ANNALS
OF
The Entomological Society of America

Volume XXII DECEMBER, 1929 Number 4

THE FOLDED-WINGED WASPS OF THE BERMUDAS, WITH SOME PRELIMINARY REMARKS ON INSULAR WASP FAUNÆ.

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Through the whim of fashion, which affects Science as well as every other human institution, it has come to pass that in biogeographical studies the "ecological" aspect nowadays has the center of interest; while the purely "geographical," or distributional, method, as exemplified by Wallace's work, is being sadly neglected. To make matters worse, the professional "ecologist" gives undue prominence to the strictly physiological side of the problem, *viz.* the reaction of the organism to the environment. Other equally important topics of the animal's (or plant's) biology, such as food-habits, reproduction, enemies and parasites, seem hardly worthy of his attention. At the risk of being dismissed as antiquated by the prophets of the day, I am presenting this brief paper in support of the contention that "ecology" alone cannot teach us *all* the story of the present-day distribution of animals and plants.

It is, moreover, easy to discover one of the reasons why the modern biologist so often favors the ecological rather than the distributional method in the study of biogeography. Any inquiry into the actual distribution of animals or plants presupposes a first-hand knowledge of species, genera, and families. It necessarily calls for an intensive taxonomic specialization, to which many modern biologists are unwilling to submit. Even Wallace, fifty years ago, found it necessary to restrict his investigations almost wholly to the Vertebrates. The number of species has increased tremendously since that time, necessitating a growing complexity of classification. The present-day

student of zoogeography must of necessity limit himself to much smaller groups.

Divested of the prevailing, picturesque though rather unnecessary, terminology, the problem of plant and animal distribution comes down to that of explaining why certain types of life are to be found in a given spot of the earth's surface, while others are absent. To be wholly satisfactory, the answer to this query involves the study of three different sets of factors. The first set covers the present (or actual) environmental conditions which either permit or prevent the existence of certain types. It is with this group of factors that ecology is concerned. The second set includes the conditions that governed the past (or geological) history of each taxonomic unit and of its ancestors. Although the former distribution of animals and plants was to some extent the outcome of ecological conditions at earlier geologic periods, yet it cannot be investigated by the ecologist's methods. A third group has to do with the various factors that govern migrations. Some of these may be ecological, but others certainly are not—such as topographical conditions and the inherent urge of the species to spread beyond its borders.

I believe that a careful and detailed study of the distribution of any group of animals or plants will show how closely interwoven these three sets of factors are. Any attempt at explaining present-day distribution by selecting one set and neglecting the others, can only give a distorted picture. I shall attempt to prove this contention by a cursory examination of the island distribution of the folded-winged wasps, or Hymenoptera Diploptera.

In the following discussion, the term "wasps" or "Diploptera" will be used to cover members of the family Vespidæ, which, in my opinion, comprises the following eleven subfamilies: Gayellinæ, Euparagiinæ, Masarinæ, Raphiglossinæ, Zethinæ, Eumeninæ, Stenogastrinæ, Polybiinæ, Ropalidiinæ, Polistinæ, and Vespinæ.* I do not intend to review the wasp

*These eleven subfamilies are of more or less equal taxonomic value. Their characters have been partly indicated in a former paper, (J. Bequaert, 1918, pp. 12–17), where, however, the name Epiponinæ was used for Polybiinæ. If one wishes to treat the Diploptera as a distinct superfamily, the eleven subfamilies should be raised to family rank. The time-honored division of the Diploptera into three groups—*viz.*, Masarinæ, Eumeninæ, and Vespinæ—still lingering in most text-books, is artificial and entirely inadequate for zoogeographical purposes. In the revised edition of Prof. J. H. Comstock's "Introduction to Entomology," (1924) one may find (p. 949) a characterization of the seven subfamilies found in North America.

faunæ of all islands, but shall rather select a few examples from among those that have been tolerably well investigated. The general considerations here offered have been prompted by a detailed study of the West Indian fauna, to which Dr. George Salt and I have devoted the best part of the last three years. I shall, however, only incidentally refer to this study, the results of which, it is hoped, will be published in the near future.

Ecological Factors Affecting the Distribution of Island Diploptera.

The ecological factors cover all present-day environmental conditions that may affect the life of wasps—the term environmental being used in the broadest sense, to include even competition with other individuals of the same or of different species.

The peculiar conditions of an insular environment become more pronounced as the size of the island decreases. Foremost among them are the climate, which is generally of the maritime type, that is more humid and cooler (or at least more equable) than that of the neighboring mainland. In many cases insular climates are regulated by ocean currents rather than by atmospheric factors. Insular climatic conditions are unfavorable to the development of Diploptera, which are essentially a *megatherm* group, flourishing in tropical countries. In addition some subfamilies (such as the Masarinæ) and genera (such as *Pterochilus*) show a partiality to semi-arid, subtropical conditions. In the colder regions of the northern and southern hemispheres, Diploptera are very few in number. Six species and varieties of *Vespa* and one species of *Ancistrocerus* compose the entire wasp fauna of Alaska. The extreme cold of the winter and the very short summer probably account for the lack of Vespidæ in Iceland (which still possesses two species of *Bombus* and several Tenthredinidæ, Cynipidæ, Chalcididæ, Proctotrypidæ, Braconidæ, and Ichneumonidæ), in Nova Zembla (which still has six species of *Bombus* and several Ichneumonidæ and Tenthredinidæ), and in Kerguelen. The distaste of the Diploptera for a cool and moist climate is well shown in the Hawaiian Islands, which possess a rich wasp fauna; yet, as Perkins (1913 *b*, p. 679) notes, no species of *Odynerus* has been able to enter the densest and wettest virgin forests of those islands, although some of the bees have occupied such forests, in spite of the sun-loving habits of the group.

The wind is a climatic factor which affects wasp-life even more directly than humidity and temperature. It is generally admitted that it tends to reduce the number of flying insects in islands that are small, low, and situated in zones of frequent gales. It is reasonable to regard this factor as accounting partly for the very small wasp fauna of most of the Antilles, especially of the Lesser Antilles, which are often visited by violent hurricanes. The apparent inability of the Diploptera to dispense with flight and to produce apterous forms has placed them at a disadvantage when compared with other groups of winged insects, such as ants, Diptera, or Coleoptera. As we shall see, the Bermudas have only three species of wasps (two of them introduced), while they still possess eleven species of ants (W. M. Wheeler, 1906). The extensive archipelago of the Bahamas has no less than 56 species and varieties of ants (W. M. Wheeler, 1905) and only ten species and varieties of wasps (according to unpublished data). In Jamaica there are some seventy species, subspecies, and varieties of Formicidæ (W. M. Wheeler, 1917) and only eight species of Diploptera. Twenty-one forms of ants have been found in Barbados (W. M. Wheeler, 1923), while the only two species of wasps of that island are probably of human introduction. Six species of ants (W. M. Wheeler, 1922) are known from Easter Island, a small island of the southern Pacific, where the only species of wasp is the widespread *Polistes olivaceus* (Degeer) (= *hebraeus* Fabricius).

The darker coloration, or tendency to melanism, often exhibited by insular animals (especially by insects), has been attributed to the influence of a moist and cool climate. On the continents melanism is also frequent in regions densely covered with humid rain forests, particularly at higher altitudes in tropical mountains. I am inclined to believe, however, that the darkening of the integument is the effect of decreased insolation, owing to the increased cloudiness and the frequency of fogs, rather than of the lower temperature and higher atmospheric dampness.

The Diploptera offer us two examples of melanism in insular faunæ. The first concerns the two closely allied West Indian species, *Pachodynerus cinerascens* (Fabricius) and *P. atratus* (Fabricius), which form the peculiar subgenus *Monobiella*, restricted to Porto Rico, the Virgin Islands and St.

Croix. These wasps are entirely black (except for an ivory white stripe over the clypeus in the male of *P. atratus*) with violaceous black wings. They have no close relatives on the South American continent or in the other Antilles and must be regarded as the offshoots of an ancient, autochthonous, Antillean stock.

The other case is that of the Hawaiian wasp fauna, the peculiarities of which will be pointed out in the sequel. In his account of the color-groups of Hawaiian wasps, R. C. L. Perkins (1913 *a*, pp. xciii-xcvii and 1913 *b*) discusses at length the melanism of these insects. He writes: "The general tendency to blackness of the Hawaiian Aculeata, as a whole, is one of their most remarkable features. The blackness of these insects is increased by the dark color of their wings, which in a large number of the species exhibits striking blue or purple reflections. The result of this is to produce a great superficial resemblance between many of the bees, wasps and fossorial wasps. Though similar phenomena appear in the Aculeates of other countries, I know no case quite comparable in extent with that observable in this fauna. We are not able to suggest any satisfactory explanation as to the cause of this widespread melanism. Were it universal it might certainly be considered protective, for the result is conspicuousness, but the allied species that lack the blackness thrive as well as those that possess it." The 35 species of Eumeninæ known from the island of Hawaii fall into three color-groups: 17 species (or 48 per cent.) are entirely black with dark wings; 10 species (or 28 per cent.) are mostly black, but with the thorax and abdomen more or less marked with reddish and the wings dark; 8 species (or 24 per cent.) are of the more usual eumenine color-type, that is black with one or two yellowish or whitish abdominal bands; but even in these, the bands are narrower than usual and the wings are more or less infuscate.

The food supply is affected directly or indirectly by the amount of plant-growth. In the case of most Diploptera the effects are indirect, through the possibilities for feeding given to the insect larvæ on which the wasps prey. The only group of wasps that are strictly vegetarian—both as larvæ and as adults—is the subfamily Masarinæ, which is not represented in any insular fauna. Barring a few exceptional cases, it is a fairly general rule that the larger the island the greater will be the luxuriance of the vegetation and the variety of the flora.

We may expect that the amount of insect life will often be in direct proportion to the size of the island. The factor "food-supply" is, however, closely correlated with the mode of formation of each island. Since the larger islands are always the remnants or outliers of continental areas, their present flora and fauna are to a large extent derived from a former continental stock. As the size of the land gradually decreased through submergence, some of the autochthonous plants became extinct through the combined effects of keener competition and modified environment. The drop in the plant population was inevitably followed by a decrease in the number of insects. On the other hand, truly oceanic islands (that arose from the ocean) have been entirely populated by migrants, or waifs. Every new species of plant that settled the islands increased the possibilities for a richer insect fauna.

We can therefore only compare islands that have had a similar origin. An excellent illustration of the relation between size and fauna is afforded by the Greater Antilles, all of which are fragments of a former continental area of land. Their total wasp fauna comprises 43 species and varieties: of these 23 are found in Cuba and the adjoining Isle of Pines (area: 44,000 square miles); 15 in Santo Domingo (area: 28,250 square miles); 7 in Jamaica (area: 4,200 square miles); and 6 in Porto Rico (area: 3,500 square miles).

Geological Factors.

According to their former history, we may, with A. R. Wallace (1881), classify the islands into three main groups.

(1) Continental Islands (Wallace's Recent Continental Islands). These are islands that at some time during their geological past have been part of a neighboring continent, with which they agree in geological structure. The separation from the mainland came about either through subsidence of the coast, or through erosion, or through seismic movements. In many cases their severance is, geologically speaking, of recent date or was not complete until modern times. Often the channel which separates them from the continent is narrow, so that it is practically non-existent for powerful flying insects, such as wasps. The recent separation from, and the close proximity to the mainland sufficiently explain why the wasp faunæ of continental islands show no distinctive features.

In Europe the British Isles afford a classical example of continental islands. They became separated from northern France toward the close of the Pleistocene. Their wasp fauna comprises only twenty-five species, belonging to the Holarctic genera *Eumenes*, *Odynerus*, *Symmorphus*, *Ancistrocerus*, and *Vespa;* all the species being found on the continent of Europe. The present poverty of the wasp fauna is due to three factors: (a) the maritime, humid climate is, as I have explained before, unfavorable to the Diploptera; (b) Great Britain was severed from the continent at the end of the last glaciation, before meridional types of wasps (such as *Discoelius* and *Pterochilus*) could migrate into western Europe; (c) much of the original fauna has undoubtedly been destroyed by man.

In North America, Newfoundland, the small islands along the coast of New England (Mt. Desert, Nantucket, Martha's Vineyard), as well as Long Island, are also of recent continental origin and their wasp fauna likewise shows no individuality.

Trinidad is perhaps the most instructive of all continental islands from our point of view. Although still included by many geographers among the West Indies, it is in reality but a detached bit of Venezuela, from which it is now separated by a broad gulf and by two channels in some places only a few miles wide. It is 55 miles long and 40 miles wide, covering an area of about 1,750 square miles. Some parts are extremely rugged, reaching an altitude of 3,012 ft. at the peak of Tucutche. It is still heavily wooded and its flora and fauna are the same as those of the Venezuelan mainland, but totally different from those of the Lesser and Greater Antilles. The South American character is well shown by the following list of species of Diploptera at present known from Trinidad (although this is probably a mere fragment of the actual fauna): *Odynerus antillarum* Provancher, *O.* (*Stenodynerus*) *cyphosus* Zavattari, *Pachodynerus praecox* (H. de Saussure), *Eumenes cinctus* Provancher, *E. flavopectus* Provancher, *E. impunctus* Provancher, *Monobia* (two apparently undescribed species), *Apoica pallida* Lepeletier, *Synoeca surinama* (Linnaeus), *Polybia bifasciata* H. de Saussure, *P. occidentalis* (Olivier), *P. rejecta* (Fabricius), *Polistes canadensis* (Linnaeus) (typical color phase), and *P. pacificus* var. *geminatus* Fox. Only two of these species are known from the Antilles, *viz.*, *Polybia occidentalis*, which has invaded the southernmost of the Lesser Antilles (Grenada and, perhaps, St. Vincent);

and *Polistes canadensis*, of which a peculiar color phase (var. *cinctus* Lepeletier) is characteristic of most of the Lesser Antilles. These two exceptions rather confirm than impair the view that Trinidad (as well as Tobago and the archipelago of Curaçao) must be eliminated from any consideration of the West Indian fauna.

(2) RESIDUAL ISLANDS (Wallace's Ancient Continental Islands). The islands of this second group are remnants of a former continent that, after a shorter or longer history as such, subsided for the most part beneath the ocean, leaving only an archipelago or a series of disconnected islands. The fauna of such islands possesses, as a rule, a number of relics or residual forms of life which give it a marked individuality. In most cases too, they have been separated from the nearest continent for a long time. Their fauna is often not homogeneous; but in addition to the decendants of an old autochthonous stock, they may contain elements that were brought in by ancient and recent migrations.

Corsica and Sardinia, in the western Mediterranean, are the remnants of a continent (Tyrrhenis) that persisted throughout most of the Tertiary, when it was connected with southern France and Tuscany. The wasp fauna of these islands consequently differs little from that of southern Europe.

The Greater Antilles (Cuba, Jamaica, Santo Domingo, and Porto Rico) formed toward the close of the Tertiary one very large island (Antillea), which may have been at various times connected with southern Florida and Yucatan. The original fauna of this continent was probably very rich, as shown by the numerous fossils. Even at the present time it shows much variety in certain groups, such as terrestrial mollusks. It is, however, rather poor in insects. According to a careful study of abundant material by Dr. G. Salt and myself, the Diplopterous fauna of the Greater Antilles comprises 37 morphological species (two of them doubtful) and 6 color varieties. Of these 43 forms, 36 (or 83 per cent.) are restricted to the Greater Antilles, 4 are also found either in the Bahamas or in some of the Lesser Antilles, and 3 only extend outside the West Indian Subregion. Most of the endemic species appear to have no close relatives elsewhere and we regard them as the offspring of the primitive, autochthonous, Antillean wasp fauna. A few species may have been derived from ancient immigrants

from the continent, since they have had time to develop into endemic, though closely allied, forms. The Antillean *Polistes crinitus* (Felton) and its several color phases (one of which has invaded the southeastern United States) are structurally very similar to *Polistes versicolor* (Olivier), the males alone presenting some slight morphological differences. These two species certainly had a common ancestor which may have migrated from Central America to Jamaica, Santo Domingo, Porto Rico, and the Bahamas. That *P. crinitus* was not a member of the autochthonous fauna of Antillea is indicated by its being absent from Cuba. Finally *Pachodynerus nasidens* (Latreille) appears to be a very recent migrant into the Greater Antilles, where it may have been introduced by the agency of man.

Madagascar, the neighboring archipelagos of the Comoros, Seychelles, Amirantes, Aldabra, and some other smaller islands are the remainders of a very large continent that at one time occupied much of the Indian Ocean and was broadly connected with East Africa. It probably became separated from the African continent about the middle of Mesozoic times. The actual fauna of these islands presents so many striking peculiarities that some zoogeographers have regarded them as forming a distinct "Malagasy Region." The affinities of the wasp fauna, however, are Ethiopian, though endemicity is extremely pronounced. There are about 65 species and color varieties of Diploptera belonging to the genera *Labus* (2), *Eumenes* (4), *Pachymenes* (1), *Odynerus* (11), *Belonogaster* (10), *Ropalidia* (30), and *Polistes* (7). Of these 65 forms, 57, or 87 per cent., are endemic; the remaining 8 forms comprising four endemic color phases of Ethiopian species, two forms widely distributed on the African continent, and two species known from the Oriental Region. The two Oriental types, *Polistes macaensis* (Fabricius) and *Odynerus trilobus* (Fabricius), are, I believe, recent immigrants into the Malagasy islands, where they were perhaps imported by man. Although there are no endemic Malagasy genera of wasps, the individuality of the fauna is greatly enhanced by the numerous species of *Belonogaster* and *Ropalidia*, some of which have peculiar leaf-green color markings found nowhere else throughout the range of these genera. It should be noted that while *Ropalidia* is found throughout the Old World tropics, *Belonogaster* is a strictly Ethiopian genus. The most important difference from the wasp fauna of the

Ethiopian continent is negative, *viz.* the absence in the Malagasy islands of the genus *Synagris*, the most truly Ethiopian type of wasp, as well as of *Raphiglossa*, *Zethus*, *Paramischocyttarus*, *Polybioides*, and the subfamily Masarinæ, all of which are well represented on the African mainland.

(3) Oceanic Islands. Many islands, especially among those of small size, have never had any connection with a continental land-mass, but have arisen in mid-ocean. They either are the product of volcanic eruptions (as in the case of the Hawaiian Islands) or have been built up from slowly emerging coral reefs (as, for instance, the Bermudas, the Bahamas, and many of the low islands in the South Seas). It is evident that, as Wallace states, "all the animals which now inhabit such oceanic islands must either themselves have reached them by crossing the ocean, or be the descendants of ancestors who did so." The factors which influence possible migration of Diploptera to oceanic islands will be examined later. It should be kept in mind that the mode of formation and not its distance from a continental shore, decides the oceanic nature of an island.

The wasp fauna of most truly oceanic islands is known to be very scant, even considering the insufficient exploration of the entomology of many islands. The case of the Bermudas will be examined at length in the sequel. In the West Indies, the Bahamas, although arising from an extensive bank that probably at one time connected Florida with Cuba, yet are entirely of oceanic formation, being built of coral limestone and wind-drift. They consist of numerous islands covering about 5,700 square miles of dry land. As known at present, the Bahaman Diploptera comprise 10 species and varieties, half of which are endemic, the others being found in Cuba also. The endemic forms are, however, very closely allied to species of Florida or Cuba, from which they have been derived at some comparatively recent date. The rather large wasp fauna of the Bahamas is due to the extent of the archipelago and to the proximity of some of the islands to either Florida, Cuba, or Santo Domingo.

Owing to the untiring zeal of R. C. L. Perkins no insular insect fauna is better known than that of the Hawaiian, or Sandwich, Islands. Fortunately for our purpose this archipelago possesses an unusually rich wasp fauna. It consists

of eight larger islands and a number of islets and reefs, scattered over a distance of about 1,800 miles, a little within the Tropic of Cancer. They are among the most isolated portions of land surface, the nearest continent being North America, about 2,100 miles away. Even the nearest islands are still very remote and separated by enormous depths of ocean. The whole archipelago is of oceanic origin, built up by volcanic eruptions in mid-ocean. Disregarding the many introductions by man, the whole of the flora and fauna is due to immigration, ancient and recent.

The insect fauna of the Hawaiian Islands is exceptionally rich. Perkins, in 1912, knew 3,325 species, 2,740 of which he regarded as belonging to the natural fauna. He estimated that about half of the existing species of native insects had been collected at that time. A number of factors have contributed to the richness of the fauna. In the first place, the archipelago is certainly very old. Volcanic eruptions have produced islands in this region since the remotest geological periods. Some of the islands have thus become quite extensive, Hawaii, for instance, covering an area of 4,015 square miles, but little less than that of Jamaica. The general mountainous character and the high altitude cause much variety of ecological conditions. There is a great diversity of climate and on many of the islands the rainfall is abundant. The vegetation was originally quite luxuriant and is still so in many parts. Of the large number of flowering plants at least 80 per cent. are endemic.

The endemic hymenopterous fauna of these islands has been so ably discussed by Perkins (1913 *a*, pp. lxxiii-cxi) that it is unnecessary to review it here in detail. The most striking feature, perhaps, is the complete absence of certain large groups, such as Chalastogastra, Cynipinæ, Psammocharidæ, Chrysididæ, Mutillidæ, and Scoliidæ. Other groups such as Formicoidea, Proctotrypidæ, Pteromalinæ, and Braconidæ, are represented by only a single species that can claim endemicity. All the truly indigenous bees, or Apoidea, belong to the family Prosopidæ. Among the fossorial wasps, or Sphegoidea, only the Pemphredoninæ and Crabroninæ are represented by endemic species.

The Diploptera now found in the Hawaiian Islands comprise first a small number of species imported by man. These are

three Polistinæ: *Polistes olivaceus* (Degeer) (= *hebraeus* Fabricius), *P. macaensis* (Fabricius), and *P. fuscatus* (Fabricius) var. *aurifer* (H. de Saussure); one of the Vespinæ, *Vespa occidentalis* Cresson; and one of the Eumeninæ, *Pachodynerus nasidens* (Latreille) (= *P. simplicicornis* H. de Saussure).*

The autochthonous, or endemic, wasp fauna consists of 112 species, a greater number than that belonging to any other group of indigenous Hymenoptera. These species all belong to the Eumeninæ, a subfamily of solitary Diploptera, and represent two genera only, *viz. Pterochilus*, with three, and *Odynerus*, with 109 species. Both these genera are cosmopolitan.† Not the least remarkable feature of this rich wasp fauna is the preciseness of the structural characters which differentiate these many species. Whereas in other parts of the world the species of *Odynerus* differ often in a few obscure morphological details, most of the Hawaiian forms offer very distinct structural characters. On the other hand, many of these insects are much alike in coloration, the whole Hawaiian wasp fauna having become divided into a small number of color-groups. The general tendency to melanism of many species has been alluded to before. Endemicity is very pronounced in most of the islands of the group, as appears from the following figures, which also show a distinct correlation between the size of each island and the number of species it possesses. Hawaii (4,015 square miles) has the largest wasp fauna, with 35 species, 29 of which (or 83 per cent.) are endemic. Oahu (598 square miles) comes next with 29 species, 26 of them (or 90 per cent.) endemic. Maui (728 square miles) has 26 species, 9 of them (or 34 per cent.) endemic. Molokai (261 square miles) has 24 species, 9 of them (or 37 per cent.) endemic. Kauai (slightly smaller than Oahu) has 17 species, all of them (or 100 per cent.) endemic. Lanai (much smaller than any of the others) has 13 species, only 3 of them endemic. It should be noted that Lanai, Maui, and Molokai lie close together and have many

*Through the kindness of Dr. F. X. Williams, I have been able to examine Hawaiian specimens of these five species.

†Perkins has created for eight of the Hawaiian species of *Odynerus* a "genus" *Nesodynerus* and for one other species, a "genus" *Chelodynerus*. The characters on which these groups are based are not, in my opinion, of generic value. The three Hawaiian species of *Pterochilus* have been placed by Perkins in a special "genus" *Pseudopterocheilus*. As long ago as 1866, it was recognized by F. Morawitz that in many species of *Pterochilus*, the female alone has ciliated or fringed labial palpi.

species in common; if treated as one area, their combined fauna has 40 species of Eumeninæ, 34 of which (or 85 per cent.) are not found elsewhere. The very high endemicity of Kauai (notwithstanding the small number of known species) is probably due to its being much farther away from its nearest neighbor than is the case of any of the other islands.*

Factors Regulating Insular Migration.

Most continental islands are so close to the mainland, that insects have, as a rule, no difficulty in reaching them either by flight or in drift. Migration in this case differs but little from the spreading of the species over continental areas. In residual islands, however, the autochthonous fauna may be added to from time to time by chance arrival of waifs from the continents or from other islands. Finally, true oceanic islands have been populated by waifs only. As the chances for new arrivals are in direct proportion to the length of time the island has been emerged, the age of the island will, as a rule, be of considerable importance in determining the size of its insect fauna.

The natural means of dispersal of flying insects are as yet insufficiently known. In the case of Diploptera some species undoubtedly have reached islands by flight, while others were carried in the larval or pupal stages within their nests attached to or hidden in drift. It is difficult to estimate which of these two methods has been most effective. We are but poorly informed as to the actual power of flight of wasps and it might be incorrect to draw conclusions from analogous observations with bees or with flying insects of other orders. Many wasps are rather clumsy fliers, especially when compared with some of the solitary bees, such as *Anthophora*. The wind is generally regarded as helpful in the dispersal of insects by flight. In the case of wasps with long and broad wings, however, it is a question whether even a moderate gale will not hamper rather than aid them, when they are blown to sea. If they lose control of their flight they will be drowned before they are many miles off shore. I am inclined to believe that the majority

*The figures here adopted differ slightly from those given by Perkins. They are based upon a careful checking up of all published records. The total number of 112 species does not include *Odynerus hawaiiensis* Blackburn and Cameron, a name which has not been properly accounted for; but the species on which it was based has certainly been described later by Perkins.

of native wasps of oceanic islands have been derived from nests that were carried in drift by ocean currents. It is significant that most of the endemic wasps of such islands belong to the Eumeninæ, a subfamily of solitary Diploptera containing many species that in the early stages live within well-sealed cavities or burrows in dead wood. The relative efficacy of wind and drift in bringing new wasps to a given island, will of course be conditioned by the direction of the prevailing winds and ocean currents, as well as by the distance from continents or other islands.

Whereas purely ecological factors are of minor importance in the process of migration, they will be foremost in deciding the ultimate fate of the new immigrants. What will happen to the waifs depends largely upon their adaptability to the new environment. As pointed out by Wallace (1881, p. 73), most insects have become so exactly adapted to one set of conditions that when carried into a new country they cannot live. Such over-specialization is not yet apparent among most groups of Diploptera, except in the case of the Masarinæ, whose food supply—for the larvæ as well as for the adults—is wholly derived from the nectar and pollen of certain flowers. The other Diploptera are still what might be called "generalized predators." Their food consists entirely or mainly of insects and every species has a rather wide range in choosing its prey. On the other hand, as I have indicated, wasps have been handicapped by their distaste for the cool and moist climate so frequent in most small islands, as well as by their apparent inability to evolve wingless forms.

The offspring of a continental species that reached an island as a waif or that was left stranded in a residual fauna, will in the course of time develop new specific forms through the usual processes of variation and natural selection. The products of this evolution will in most cases show a decided difference from the contemporary offspring of the same stock on the continent or on other islands. It is generally admitted that this process of evolution is either hastened or accentuated through the isolation of the insular fauna. As B. L. Robinson (1902) has shown, in an isolated flora or fauna specific variations may go on without restriction, except for the chance arrival of waifs of the same species from the continents; but the new waifs being in a small minority would probably be unable to

check any variation that had begun before their arrival. Insular wasp faunæ offer some beautiful examples of the effects of isolation. The case of the Eumeninæ of the Hawaiian Islands has been discussed before. The genus *Eumenes* contains two well-defined species, each restricted to an island and yet clearly derived from a widely distributed ancestor. *Eumenes alluaudi* Pérez is a precinctive species of the Seychelles and Gloriosa Islands, which finds its nearest relative in the African *E. maxillosus* (Degeer) (See J. Bequaert, 1921). A parallel case is afforded by *Eumenes germaini* Lucas, endemic in New Caledonia and the Loyalty Islands and evidently derived from the common, Oriental species, *Eumenes pyriformis* (Fabricius). It is of interest that in both cases these precinctive species of *Eumenes* replace what apparently is their ancestral form, which still occurs in neighboring islands. For, although color phases of *E. maxillosus* are common in Madagascar and the Comoros, none have been collected in the Seychelles and Gloriosa Islands. Likewise the color phases of *E. pyriformis* are absent from New Caledonia and the Loyalty Islands, while still occurring in the New Hebrides.

Almost every island now contains in its wasp fauna one or more species that have been imported by man. In the discussion of any insular fauna it is essential to recognize these as such. As Perkins rightly remarks, owing to our very incomplete knowledge of the insect fauna of the world, some of the introduced species may not yet be recognized outside the particular island whose fauna is being investigated. The current, unfortunate tendency to describe every trifling variation as a new "species" or "race," also helps to obscure the problem.

Polistes is a genus of social wasps which is at present found in almost every island with a temperate or warm climate. While the species that show morphological characters are relatively few in number, they often vary tremendously in color, so that they have led to the introduction of many names. For instance, over one hundred so-called "specific" names have been proposed for the *Polistes* of North and South America, but it is doubtful whether there are more than thirty valid species in the New World. When specimens of *Polistes* have been collected in islands they have generally been described as new, endemic species. Thus we have *Polistes ridleyi* Kirby, described from Fernando de Noronha, an islet of the Atlantic, 200 miles

off Cape San Roque; and *Polistes fortunatus* Kirby, described from the Cape Verdes. An examination of the type of *P. fortunatus* has shown that this wasp is a color phase of the American *Polistes fuscatus* (Fabricius), and there can be little doubt that it was imported into the Cape Verdes by man. Moreover, some species of *Polistes* are rather readily carried by ships into new territory, owing to their habit of frequenting human habitations where they often build their paper nests. The European *Polistes gallicus* (Linnaeus), for instance, is not now a member of the indigenous fauna of the British Isles; yet specimens are captured from time to time in England. Perkins (1917, Ent. Mo. Mag., LIII, p. 229) suspects that it "has been not infrequently brought over [to England] with shrubs or in other ways, and has once in a while started a colony only to be sooner or later exterminated by our climate." In his interesting study of the migration and dispersal of insects, J. W. Tutt (1902, Ent. Record, XIV, p. 208) writes: "A South American wasp, *Polistes bipustulatus* [a color phase of *P. versicolor* (Olivier)], was taken at Ince, near Liverpool, during an excursion of the Liverpool Nat. Field Club, in the summer of 1875; the same species had been taken in the London Docks by Douglas, in 1868, whilst in Ent. Ann., 1868, p. 87, and 1869, p. 68, the same Brazilian species is recorded as being taken at Penzance in 1866 and 1867, undoubted importations." As we have seen, three species of *Polistes* have been imported by man into the Hawaiian Islands: *P. olivaceus* (Degeer) and *P. macaensis* (Fabricius) came from the Oriental Region, while *P. fuscatus* var. *aurifer* (H de Saussure) was brought from California. One of these species, *P. olivaceus* (Degeer) (= *hebraeus* Fabricius), appears to have unusual facilities of travel. It is now so widespread throughout the Oriental and Australian Regions and Polynesia, that its original home is difficult to define. That it owes its occurrence in many islands to accidental introduction by man is beyond doubt.

The Bermudas.

The Bermudas, also called Somers or Summer Islands, are a compact archipelago of nearly three hundred islands, cays, and reefs, isolated in the Atlantic Ocean, in north latitude 32° 14′ to 32° 23′ and in west longitude 64° 38′ to 64° 52′. The nearest land at Cape Hatteras, North Carolina, is 568 nautical miles

(or 620 statute miles) to the west; the distance to the nearest West Indian island (Abaco, in the Bahamas), is about 700 nautical miles (or 850 statute miles). The emerged land covers an area of a little over nineteen square miles. At one time the archipelago was much more extensive, for the outer reefs are the eroded remains of limestone islands larger than any of those still left. All the solid rock now at or near the surface is an Aeolian limestone, of recent geologic age, made of a hardened mixture of coral, shells, and sand, drifted by the wind. Many caves and grottoes have been eroded in these rocks. A deep-well boring has shown that at about 360 feet below the surface, the limestone cap rests upon rocks of volcanic origin. Loose superficial soil is scarce, but there are still a few moving sand-dunes. The islands are hilly, the hills being consolidated sand-dunes, many reaching over 200 feet. The highest point is 268 feet above sea-level. There is no permanent running or standing fresh water.

As in all low islands of small extent, the climate is dominated by the temperature of the surrounding waters. Being in the path of the warm waters of the Gulf Stream, the Bermudas have a remarkably equable climate for their latitude. In winter and spring the temperature averages 59° F. to 66° F.; frosts are exceptional and light. In summer the average rises to 81.7° F. The annual average is about 70° F. The total rainfall averages 51.4 inches a year and is fairly evenly distributed over the seasons. It is greatest in winter, when cold, northerly winds prevail. During the summer showers are few and of brief duration, but the air is then moist and sultry. Perfectly calm days are rare; the winds are often very strong and hurricanes occasionally visit the islands.

When first discovered by Europeans, about the year 1510, the Bermudas were uninhabited and all densely wooded with cedars (*Juniperus bermudiana* Linnaeus) and palmettoes (*Sabal Blackburnianum* Glazebrook). The islands are now denuded of forest and have become dry and barren, being covered with hardy shrubs and grasses. There are extensive stretches of cultivated land. The native flora of the Bermudas originated from seeds, spores or other parts brought from the North American mainland or from the West Indies by the natural agencies of wind, ocean currents, and birds. The present flora comprises about 449 species of flowering plants, but of

these only 146 are regarded by N. L. Britton as having reached the Bermudas independently of human activities. There are very few endemic flowering plants (11 species in all), the most noteworthy being the cedar and the palmetto. Even including the cryptogamic plants, only 8.7 per cent. of the total native flora is endemic; while about 80 per cent. of the native land plants inhabit the West Indies or southern Florida, or both.*

According to A. E. Verrill, the pre-Pliocene fauna and flora was exterminated by the Glacial Period, so that most of the present native life reached the islands since the latter part of the Pleistocene. The terrestrial fauna is very poor, even for oceanic islands. Much of it has probably been destroyed by man. We know that this happened to several of the indigenous birds. The changes in ecological conditions which followed deforestation undoubtedly caused the disappearance of many species of insects. On the other hand, some of the birds, reptiles, amphibians, and insects that were accidentally or purposely introduced by man may have killed off some of the native insects. Some of the tramp species of ants are particularly powerful agents of extermination. (See W. M. Wheeler's notes on *Pheidole megacephala* Fabricius in the Bermudas). Finally, no serious investigation of the land fauna of the Bermudas has as yet been attempted.

For all these reasons one must be cautious in attempting to discuss the origin of the Bermudan insect fauna. Condensing the information available in 1902, A. E. Verrill states that of the 225 species of insects identified from the islands, more than 90 per cent. belong also to the fauna of the United States; a few are European; perhaps a dozen are peculiarly West Indian, and two only are precinctive. One of these is the large locust, *Tibicen bermudiana* (Verrill), which was mentioned as early as the year 1619. It is closely allied to *Tibicen lyricen* (Degeer), of the eastern United States, though distinct. W. T. Davis (1919, Jl. New York Ent. Soc., XXVII, pp. 242–243) has expressed the opinion that *T. bermudiana* is probably the result of a stray *T. lyricen* having reached the Bermudas at a remote period. Many of the species listed from the islands are either domestic or at least cosmopolitan insects. Verrill concludes from his review: "The relatively small number of species

*For a general account of the Bermudas, consult A. E. Verrill (1902–1903). The flora has been fully treated by N. L. Britton (1918).

hitherto obtained is very remarkable and is good evidence of the very meager insect fauna, though many species must still remain to be discovered." (1902–1903, p. 740).

The Hymenoptera of the Bermudas.

The following brief discussion of the Bermudan Hymenoptera, other than Diploptera, is based partly upon published records, especially those contained in papers by A. E. Verrill (1902–1903), W. M. Wheeler (1906), and L. Ogilvie (1928*b*). I have, however, also used unpublished data found in three collections. One of these was made by Mr. Austin M. Brues in 1913; the two others are in the Museum of Comparative Zoology of Harvard University, one made by Miss E. B. Bryant during July and August, 1921, and the other by Mr. W. S. Brooks in January and February, 1928.

In the Aculeata, the bees are represented by three species. One of these, the honey-bee (*Apis mellifera* Linnaeus), was introduced by the early settlers (before 1679). The other two appear to be endemic or at least to have reached the islands by natural means. They are both solitary bees. *Halictus semiviridis* Friese (1908, Zool. Jahrb., Suppl. Bd. XI, 1, p. 37) is a small species, which, as pointed out to me by Miss Grace Sandhouse, seems to be more like some of the North American species (particularly *H. nymphaearum* Robertson) than any of the West Indian. It is a common insect, as I have seen many specimens of it, including the undescribed male. It is the *Augochlora* and *Halictus* of Ogilvie's list. Ogilvie also mentions having found an undetermined species of *Megachile* nesting in walls and a female of what is probably the same species of bee was collected by Mr. Austin Brues.*

Only three species of fossorial wasps are known from the islands. Two of them are most probably recent introductions by man—*viz.*, the Sphecidæ, *Sceliphron caementarium* (Drury) (= *Pelopaeus flavipes* and *Sceliphron fasciatum* of Verrill's list) and *Chalybion cyaneum* (Klug) (= *Chalybion caeruleum* of authors, not of Linnaeus). Both are common mud-daubers of the eastern United States, that often nest in houses or even on board ship, the mud nests being easily transported with timber

*The specimen collected by Mr. Austin Brues has now been described as *Megachile pruina bermudensis* Mitchell, 1929, Psyche, XXXVI, p. 93.

or in furniture. The *Sceliphron* appears to be the more common of the two in the Bermudas and is the only one included in Miss Bryant's collection. According to F. Kohl (1918, Ann. Naturh. Hofmus. Wien, XXXII, p. 117), the Bermudan specimens belong to the typical color form of *S. caementarium* (Drury). The third fossorial wasp is a small species of the family Psenidæ (or Mimesidæ) and belongs to the subgenus *Mimesa* of the genus *Psen*. The pair collected by Miss Bryant show that it is very closely allied to *Psen* (*Mimesa*) *niger* Packard, of the eastern United States, if not identical with that species. Since some of the species of *Psen* are known to nest in wood or in the pith of twigs, they may be transported in drift. The possibility of the Bermudan *Psen* being a human introduction can, however, not be entirely excluded.

F. Dahl (1892) recorded from the Bermudas a digger wasp of the family Psammocharidæ, which he referred to the common North American species, *Psammochares philadelphicus* (Lepeletier). Ogilvie however, did not find this species, but he lists instead *Psammochares funereus* (Lepeletier) and *P. scelestus* (Cresson). In the collection made by Mr. Austin Brues, I find three females of a *Psammochares* belonging to the subgenus *Anoplius* and apparently quite closely allied to the common *P. virginiensis* (Cresson) of the eastern United States.

The family Formicidæ, or true ants, is one of the few groups of Bermudan insects that are tolerably well known. W. M. Wheeler (1906) lists eleven species as reported from the islands, but three of these he had not seen himself. All belong to the cosmopolitan or tropicopolitan genera, *Ponera*, *Odontomachus*, *Monomorium*, *Cardiocondyla*, *Pheidole*, *Tetramorium*, and *Prenolepis*, the New World genus, *Brachymyrmex*, and the Holarctic genus, *Lasius*. Most of these ants are widely distributed species, several of them being well-known tramps. The single endemic ant, *Prenolepis kincaidi* Wheeler, is regarded by Wheeler as probably of West Indian origin.

Of parasitic Hymenoptera, the families Evaniidæ, Ichneumonidæ, and Chalcididæ are represented. One of the cosmopolitan coackroach parasites of the genus *Evania* appears to be common. Verrill and Ogilvie refer the species to *E. appendigaster* (Linnaeus) (= *E. laevigata* of Jones, 'Guide,' p. 142). Since, however, a second species, *E. punctata* Brullé (= *E. urbana* Bradley), is equally common in the cities of

the eastern United States, the specific identity of the Bermudan insect should be more carefully investigated. Unfortunately there are no specimens in any of the collections that I have examined. Both these cockroach parasites have been imported by man from the Old World in the egg-cases of their hosts.

In the collections which I have seen, there are at least five species of Ichneumonidæ (belonging to four genera), five species of Braconidæ (belonging to as many genera), and five species of Chalcididæ (of the subfamilies Chalcidinæ, Eurytominæ, and Pteromalinæ). Verrill states that several undetermined Ichneumonidæ were obtained and adds: "Among them is a species of *Ophion* very much like our common large species (*O. macrurus*)." (1902-1903, p. 754). On p. 889, he lists in the Addenda "two small Ichneumon-flies, of the genera *Limneria* and *Cratichneumon*, determined by W. H. Ashmead; and two other species." The so-called *Ophion* is a species of *Enicospilus*, a genus with many representatives in North America and the West Indies. Ogilvie refers the Bermudan species to *E. concolor* (Cresson); but a female taken by Mr. Brooks has been identified as *E. flavus* (Fabricius) by Professor C. T. Brues. It certainly agrees with the description and figure given by C. W. Hooker (1912, Trans. Amer. Ent. Soc., XXXVIII, p. 71, Pl. III, fig. 24) of *E. flavus*, a species widely distributed on the American continent (from New Jersey to the Guianas), as well as throughout the West Indies. The very large ocelli indicate that this parasitic wasp, like so many other Ophioninæ, is nocturnal or crepuscular. Ogilvie also lists *Paniscus rufus* Brullé as taken by him in the islands. Of Braconidæ, Ogilvie records *Opius humilis* Silvestri, introduced from the Hawaiian Islands to control the Mediterranean fruit-fly, *Ceratitis capitata* (Wiedemann) (see Ogilvie, 1928*a*); *Apanteles solitarius* (Ratzeburg), *Aphidius testaceipes* (Cresson), *Diaeretus rapæ* (Curtis), *Calyptus* sp., and *Phaenotoma* sp. Among the Chalcididæ he lists one species of Eupelminæ: *Lecaniobius cockerelli* Ashmead; and four species of Aphelininæ: *Aphelinus diaspidis* Howard (introduced in 1921-1924); *Prospaltella berlesei* Howard (introduced in 1921-1924); *P. diaspidicola* Silvestri (introduced in 1921-1924); and *Coccophagus flavoscutellum* Ashmead.

The following important groups of Hymenoptera have no known representatives in the Bermudas: Chalastogastra, Proctotrypoidea, Cynipoidea, Chrysididæ, Mutillidæ, and Scoliidæ.

THE DIPLOPTERA OF THE BERMUDAS.

The folded-winged wasps, or Vespidæ, are represented in the Bermudan fauna by three species only, *viz. Vespa arenaria* Fabricius, *Polistes fuscatus* (Fabricius), and *Odynerus bermudensis* Bequaert. The *Vespa* and the *Polistes* have evidently been introduced by man from the North American continent. The *Odynerus*, here described for the first time, may be endemic; but its affinities are with the North American, not with the West Indian, fauna.

1. **Vespa arenaria** Fabricius.

Vespa arenaria Fabricius, 1775, Syst. Entom., p. 365 (sex not given). J. Bequaert, 1928, Bull. Brooklyn Ent. Soc., XXIII, p. 54, (worker, holotype of Fabricius).
Vespa diabolica H. de Saussure, 1853–1855, Et. Fam. Vesp., II, p. 138 (♀ ♀). R. du Buysson, 1905, Ann. Soc. Ent. France, LXXIII, 4, p. 571, Pl. VI, Fig. 4.
Vespa vulgaris J. M. Jones, 1876, 'The Visitor's Guide to Bermuda,' p. 142, (not of Linnaeus).

I have seen one of the workers of this yellow-jacket collected by J. M. Jones in the Bermudas and sent by him to the Peabody Museum. It is now at the Museum of Comparative Zoology. The species does not appear to have become naturalized in the island, since none of the later collectors have seen it there.

V. arenaria is extremely common throughout North America from the Atlantic to the Pacific coast and from southern Alaska to New Mexico.

2. **Polistes fuscatus** (Fabricius).

Vespa fuscata Fabricius, 1793, Entom. Syst., II, p. 260, (sex not given).
Polistes perplexus Cresson, 1872, Trans. Amer. Ent. Soc., IV, p. 245, (♂). W. F. Kirby, 1884, Ann. Mag. Nat. Hist., (5) XIII, p. 410. Verrill, 1902–1903, Trans. Connecticut Ac. Arts Sci., XI, 2, p. 751, Figs. 106 (♂) and 107 (♀). Ogilvie, 1928, 'The Insects of Bermuda,' p. 49.
Polistes pallipes J. M. Jones, 1859, 'The Naturalist in Bermuda,' p. 113. Ogilvie, 1928, 'The Insects of Bermuda,' p. 49.
Polistes canadensis J. M. Jones, 1876, 'The Visitor's Guide to Bermuda,' p. 142, (not of Linnaeus).
Polistes bellicosus Ogilvie, 1928, 'The Insects of Bermuda,' p. 49, (not of Cresson).

Polistes fuscatus was originally described from the Antilles and I have seen specimens from Barbados that agree quite well with Fabricius' description. In coloration they can be easily matched with some of the Bermudan specimens. I have also seen two males, similarly colored, from Jamaica. Moreover, I regard the Antillean and Bermudan *P. fuscatus* as

specifically identical with the common North American species generally called *Polistes pallipes* Lepeletier and its multiple color phases. I am unable to find structural characters that might separate these several color forms in either sex. One of the color phases of this "species" has been described by Cresson from Texas as *Polistes perplexus*, and the differences in color between this insect and typical *P. fuscatus*, of the Antilles, are so slight that I do not believe it possible to regard *perplexus* even as a distinct color phase.

In North America the *fuscatus-perplexus* coloration is not restricted to Texas, but I have seen similarly colored specimens from Mississippi, Alabama, Virginia, and New Jersey. Moreover, one may find every gradation in color to the var. *pallipes* (Lepeletier) which represents the extreme melanistic color phase of *P. fuscatus*. The many color variations of *P. fuscatus* in North America, as well as the synonymy of this species, will be discussed in the forthcoming revision of the West Indian wasps.

In view of the fact that *P. fuscatus* is the most common social wasp of North America, while in the West Indies it has been taken only in Barbados (where it is common) and in Jamaica (where it is very rare), I am inclined to regard this wasp as not a true member of the West Indian fauna, but as having been introduced by the agency of man into Jamaica and Barbados, as well as into the Bermudas. It was most probably carried from the coast of Virginia or the Carolinas to the Bermudas and thence to Barbados. Historical accounts show that at one time many vessels traded between the Bermudas and the West Indies, especially Barbados.

P. fuscatus is, as J. M. Jones (1872, p. 142) states, "the most common insect of the order Hymenoptera" in the Bermudas. It is present in all the collections made in the islands. I have seen many females, workers, and males obtained by H. H. Whetzel, T. S. Bradlee, F. M. Jones, H. F. Schwarz, and Miss E. B. Bryant. According to Ogilvie its vernacular name is "Spanish bee." The coloration of all these Bermudan specimens is rather uniform and has been fully described by A. E. Verrill (1902-1903). The two yellow, longitudinal stripes of the propodeum, however, are more often lacking than present. It is noteworthy that, in the female and worker, the clypeus, inner and outer orbits, oculo-malar spaces, and mandibles are

pale yellow, very slightly suffused with ferruginous, which is also true for the specimens from Barbados.

In his 'Naturalist in Bermuda' (1859, p. 113) J. M. Jones gives an interesting account of the habits of *P. fuscatus*, which, he says, is "commonly known to the inhabitants as the 'Bermuda Wasp.' The nest, or, more properly speaking, comb, of this species, is usually fastened to the branches of the wild sage (*Lantana salvifolia*), and is about the size of a man's hand; flat, with its upper surface shiny and apparently waterproof, having the mouths of the cells reversed, or opening beneath, of which we counted some two-hundred and eighty in a specimen we brought home and presented to the British Museum. When constructing their combs in the cedar groves and cultivated parts, they appear to choose the proximity of a wall, in preference to the open, perhaps for shelter from the winds. Mr. Hurdis informs us that their combs abound in the marshes, where they hang suspended from the stems of the tall sedges. It is a cowardly insect, and is not half the plucky fellow our English wasp is, who always guards his nest with vigilance, and attacks the intruder with the greatest fury; but our friend of Bermuda will not only let you come close to his comb, but will positively allow you to cut off the branch whereon his abode rests, without any molestation on his part. It is prettily marked, of a lightish brown color, striped with bands, brown and buff, across the abdomen."

3. **Odynerus (Stenodynerus) bermudensis,** new species.

A small, cylindrical species. Black; with the legs, first tergite, and lateral spots on the second tergite, ferruginous red; head and thorax with a few yellow markings, the first and second tergites and second sternite with an apical yellow fascia.

Length (h. + th. + t. 1 + 2): ♀, 6.5 mm.

Female: Head, seen in front, subcircular, a little higher than wide; seen from above, transverse but long, about twice as wide as long, not wider than the thorax; occipital margin with a shallow inward curve. Vertex and cheeks margined throughout by a carina which is well-marked on the occiput and much higher along the cheeks. Cheeks wide and slightly swollen in their upper half, where they are but little narrower than the upper part of the eye in profile, considerably narrowed at the lower third, where the marginal carina forms a very faint obtuse angle. Inner orbits one and one-half times as far apart on the vertex

as at the clypeus. Upper half of the frons much swollen. Ocelli in a flattened triangle, the posterior pair as far apart as from the eyes. Interocellar area with a shallow, broad depression, the sides of which are slightly raised near the posterior ocelli. Vertex without fovea. Antennæ twice as far apart as from the inner orbits, the ridge between them very blunt in its lower half, with a fine impressed line in its upper half. Clypeus broadly pyriform, about as wide as long, very slightly convex throughout; its anterior, free portion as long as the upper, interocular part; its truncate apex about one-fifth of the maximum width of the clypeus, with a slight inward curve preceded by a narrow, shiny, somewhat depressed area; the lateral angles hardly projecting, very blunt and somewhat raised longitudinally. Antennæ short; the flagellum gradually swollen from the base to the apical third; scape very slender, about half the length of the flagellum, distinctly curved; third antennal segment about one and one-half times the length of the fourth; fourth and fifth slightly longer than wide; sixth and seventh almost square; eighth to eleventh slightly wider than long; twelfth about as long as wide at the base. Mandibles much shorter than the length of the eye, straight; the apex blunt and slightly curved; the inner margin with three very superficial notches separating broad, low, blunt teeth. Thorax barrel-shaped, almost equally narrowed anteriorly and posteriorly, about one and one-half times as long as its greatest width and about as high as wide. Pronotum slightly narrowed toward the anterior margin which has a slight outward curve and is carinate; on the sides the carina is sharp and runs from the humeral angles to the coxæ; dorsally it is much finer, but is continuous across the middle; the smooth, anterior face with a pair of small, deep pits in the middle; humeral angles barely indicated, obtusely rounded. Mesonotum a little longer than wide, pentagonal in outline with the anterior third produced, slightly convex, with short traces of parapsidal furrows in front of the scutellum and with a fine raised line in the anterior third. Tegulæ about as wide as long, with broadly rounded outer margin, of normal shape; post-tegulæ narrow, finger-shaped, flat. Scutellum rectangular, one and one-third times as wide as long, flattened throughout, with an extremely fine, longitudinal, impressed line, without tubercles or carinæ; the deep suture separating it from the mesonotum finely foveolate. Postscutellum transversely elliptical, less than half as long as the scutellum, moderately convex throughout, somewhat sloping posteriorly, without ridges, tubercles or depressions. Mesepisternum completely divided into an upper and a lower plate; with a distinct prepectal carina beginning a little above the mesepisternal suture and extending to near the base of the middle coxæ. Propodeum moderately long, squarely and vertically truncate behind, hardly swollen on the sides; dorsal areas touching each other in the middle in a depressed horizontal area which is but little shorter than the postscutellum and separates it completely from the concavity; concavity wide, shallowly depressed, divided by a fine longitudinal carina which does not reach its upper edge; superior, lateral, and inferior ridges bluntly angular but not carinate; lateral angles broadly rounded. Abdomen elongate, moder-

ately slender. First tergite short, transverse, in outline cup-shaped with rounded sides, about one and one-half times as wide as long; its horizontal face, in profile, more than half the length of the second tergite; its anterior slope not forming an angle with the posterior, horizontal portion; the two areas not separated by a suture or carina; the horizontal area slightly wider in the middle than on the sides, without median depression; the hind margin hardly thickened, not produced in the middle, covering the depressed base of the second tergite; its extreme edge narrowly translucent and somewhat jagged. Second segment broadly barrel-shaped, somewhat more narrowed anteriorly than posteriorly, a little wider than long, moderately and about equally convex dorsally and ventrally; the apical margin simple, without raised or depressed lamella, the extreme edge narrowly translucent; the sternite gradually sloping and broadly rounded basally, slightly depressed medially, but without a longitudinal furrow, with a row of pronounced longitudinal riblets in the transverse furrow behind the basal articulation. No mite chamber is formed by the depressed basal neck of the second tergite. Legs slender, of normal shape. Wings with the usual type of venation; radial cell gradually and moderately widened opposite the second cubital, broadly rounded at the apex, with the stump of an appendiculate vein; third cubital much higher than long.

Head and thorax densely covered with medium-sized punctures, which are larger on the pronotum and mesonotum, smaller on the frons, and much finer on the mesopleura. Anterior face of mesopleura, sternum, metapleura, and tegulæ impunctate. Punctures of the clypeus a little finer than those of the frons, but much more widely spaced, and separated by very faint, superficial, and irregular, longitudinal striæ. Dorsal areas of propodeum rugoso-reticulate; lateral areas with fine, scattered punctures in the lower part, more heavily punctate toward the lateral ridge; concavity irregularly rugulose and with scattered, medium-sized punctures. Horizontal face of first tergite densely and fairly uniformly covered with medium-sized punctures which are distinctly larger and more irregular in the anterior part. Second tergite uniformly covered with fine, moderately dense puncturation; that of the second sternite and following segments much finer. Body shiny, with a few very short, grayish hairs on head and thorax.

Black. Base and under side of scape, apex of mandibles, most of the legs, most of the first abdominal segment, and an ill-defined, small spot on each side of the second tergite (far removed from the base), ferruginous to red. Basal third of the clypeus, a spot on the base of the mandibles, a triangular, median spot on the frons above the insertion of the antennæ, a small spot in the sinus of the eye, a narrow stripe in the upper half of the cheeks close to the orbits, four small spots on the pronotum (one on each humeral angle and one on each side of the middle line, but removed from the anterior and posterior margins), the postscutellum, most of the upper plate of the mesepisternum, tegulæ (except the ferruginous center) and post-tegulæ, the hind margin of the first tergite (widest in the middle and gradually narrowed to the

sides), the broad uniform hind margin of the second tergite, the apical corners of the second sternite, and indistinct spots at the apex of the femora and at the base of the tibiæ, pale sulphur yellow. There is a trace of a yellow dot in the ferruginous lateral spots of the second tergite.

Male unknown.

Specimen examined.—Bermuda, one female, holotype, September 1925 (L. Ogilvie.—Imperial Bureau of Entomology).

This specimen bears a female Strepsipteron protruding on the right side under the fourth abdominal tergite.

I have carefully compared this wasp with a large number of North American species of the subgenus *Stenodynerus*. It appears to differ structurally from all those that have been described thus far. The shallowly depressed interocellar area, the shape and sculpture of the clypeus, propodeum, and first and second tergites, the flat, simple apical margin of the second tergite, and the absense of a mite chamber, furnish the best characters. A species from Georgia, apparently undescribed, in my collection, comes nearest to *O. bermudensis*, but it is larger and is much more coarsely punctured on the first tergite of the abdomen.

I must provisionally regard *O. bermudensis* as an autochthonous member of the Bermudan fauna, evolved from a migrant from North America that reached the island by natural means.

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HERBERT OSBORN.

A SYNOPSIS OF THE AMERICAN ARACHNIDS OF THE PRIMITIVE ORDER RICINULEI.

H. E. Ewing,
United States Bureau of Entomology.

Ricinulids are peculiar looking arachnids which resemble superficially spiders, but are readily distinguished from the latter since they have a segmented abdomen and are without eyes. They constitute the rarest order of all the arthropods in number of specimens taken and in number of locality records obtained. Although the group is represented by well preserved carboniferous fossil forms in the North Temperate Zone, the only living examples of this order have been taken from the tropics, and in the past from two restricted areas. One of these is along the central west coast of Africa and the other is in the upper Amazon region.

But few Ricinulids have ever been collected. The first species to be taken was *Cryptostemma westermannii* Guérin. It was described in 1838 from a specimen collected by Westermann along the coast of Guinea. Many years passed after this date before another record was made. It was Bates who discovered the second species on his voyage in the Amazon Basin. This species was described by Westwood in 1874 as *Cryptocellus fœdus*. Other specimens subsequently were collected, yet when Hansen and Sörensen published their synopsis of this group in 1904 only a very few examples were available for study. They state: "As far as the number of species of Ricinulei is concerned we have consequently had much more ample material at our disposal than our predecessors, none of whom knew more than one species; but, as regards specimens, we have not been so well situated * * * because of five only out of our eight species have we had more than one specimen before us. Nor have we had any opportunity of dissecting more than one specimen, an example of *Cryptostemma crassipalpe*, for which we are indebted to the kindness of Professor C. Aurivillius." Although fossil Ricinulids have been described from the New World since Bates took his specimen in the basin of the Amazon, only one other specimen of a living

species has been taken. This one proved to be new and was described by Hansen and Sörensen as *Cryptocellus simonis* in 1904. It too was taken from the Amazon Basin.

The primitive nature of Ricinulids is indicated by their mouth-parts, their sternal characters, and the segmentation of the abdomen. Yet they stand alone among all of the more generalized arachnids in having the pedipalps immovably fused at their bases. In the Ricinulids there are certain peculiar and outstanding structures that are not properly understood at present. A very large, movable hood, the *cucullus* (Pl. III, Figs. 4 and 5), is suspended from the front margin of the cephalothorax in a vertical position. When this hood is closed the cheliceræ (Pl. III, Fig. 6) are completely hidden. The fact that this structure is provided with muscles led Hansen and Sörensen to believe that it represented a true body segment.

In males there is a peculiar modification of the third pair of legs. The basitarsus and tarsus of each are swollen, guttered and modified in a manner very suggestive of the way the palpi of certain male spiders are modified. Other peculiar structures occur, but the discussion of these shall be left for a further communication which the writer hopes to present dealing with the morphology of Ricinulids.

The present paper has been made possible only on account of the expert skill of two of our best American collectors of arthropods, Dr. W. M. Mann, now Director of the National Zoological Park and Mr. H. S. Barber, of the Bureau of Entomology. Dr. Mann collected four specimens of Ricinulids, representing as many species and coming from three Neotropical countries. Mr. Barber furnished the writer with six specimens, all belonging to the same species, and all taken at the same time, and in the same place in Guatemala.

The Proper Family Name for the Ricinulids.

Hansen and Sörensen (1904) in their excellent paper on the Ricinulei used the family name of Cryptostemmatoidæ for the two included genera of living species. In doing so they followed Westwood (1874) who first established the family, using a name based upon that of the oldest genus, *Cryptostemma* Guérin (1838).

According to McAtee and Malloch (1925) *Cryptostemma* Guérin is antedated by *Cryptostemma* Herrich-Schäffer. Herrich-

Schäffer used the name for a genus of Hemiptera, the genus being the type for the hemipterous family Cryptostemmatidæ. McAtee and Malloch claim that Dr. E. Bergroth has confirmed the date of publication (1835) of *Cryptostemma* Herrich-Schäffer. They state that "Haliday thus was mistaken about the name being preoccupied by *Cryptostemma* Guérin (Arachnida) which was published in 1838."

Scudder (1885) established the family Poliocheridæ for his new genus *Poliochera*, of the same date which was based on a Palaeozoic fossil species. Other fossil species have been added to this genus, and further study of it has shown that it is closely related to the two genera of living species. Hansen and Sörensen (1904), therefore, have rightly considered the family Poliocheridæ as a synonym of Cryptostemmatoidæ.

Petrunkevitch (1913) proposed a new family which he called Holotergidæ, for the genus *Curculioides* Buckland, the other genus of fossil species. Cockerell (1916) suggested that this name be changed because it is not based on any generic name. He proposed the name Curculioididæ in its place. *Curculioides* differs from the other genera of Ricinulids in that there are no transverse sutures visible on the dorsum. It should be remembered in connection with this character, however, that among our living species such sutures become less evident as individuals reach maturity. Also, in all species the whole abdominal tergum is entirely fused and rigid, being in fact about as thick between sclerites as elsewhere. Thus it would appear that the placing of *Curculioides* in a family by itself is hardly justified.

The rejection of the family name Cryptostemmatoidæ would make those of three different family names available for use. However, the practice of most taxonomists in always retaining the same genus for the type of the family, even although the name of this genus is shown to be preoccupied, appears to be logical. In this particular instance such a practice seems doubly important because a shifting of the type genus of the family means going from one of the living species to one of the Palaeozoic species.

In view of the fact that the order name Ricinulei is quite appropriate and has become well established, the writer first thought of using the name *Ricinulus* for the genus *Cryptostemma* Guérin, thus the name for the type genus, family and

order would all have the same stem. But, alas, the name *Ricinula* has already been used. However, *Ricinoides* appears to be unused and is available. Although not having the same stem as Ricinulei it is very suggestive of the latter name. The new family name, therefore, would be Ricinoididæ.

The Genera of Ricinoididæ.

The first genus to be established for a living species of these peculiar arachnids was *Cryptostemma* Guérin (1838), which name, being preoccupied as already stated, is here supplanted by *Ricinoides*.

Westwood (1874) established the second genus, *Cryptocellus*, for his American species *foedus*. This genus Hansen and Sörensen (1904) recognized and placed in it the second American species, *simonis* Hansen and Sörensen. Although the American and Old World species are placed in separate genera these are in fact remarkably alike. However, Hansen and Sörensen found two characters by which the then known species of *Cryptocellus* could be separated from those of *Cryptostemma*. They are the absence of the smaller apical process of the first segment of the chelicera and the much greater length of the fifth tarsal segment of leg II in proportion to the fourth. I find that these characters hold good for the four new species that are added in this paper to the genus *Cryptocellus*. In fact the differences in the ratio of the fifth to the fourth tarsal segment of leg II is even more accentuated in these new American species than in the old ones.

Fossil Ricinulids are also much like the living ones, although they have rightly been placed in different genera. However, the characters that have been used for these genera need a new appraisal. The first genus established for these extinct species was *Curculioides* Buckland (1837), erected a year before Guérin's genus, which was established for the first discovered living species.

Curculioides differs from all the other genera of Ricinulids, living or extinct, in having no evident transverse sutures to the dorsum of the abdomen. All four segments of the abdomen proper appear to be fused dorsally.

Scudder (1885) established the genus *Polyochera* for his *punctulata*, a fossil species taken at Mazon Creek, Illinois. His description follows:

"Cephalothorax scarcely longer than broad, slightly narrowing anteriorly, the front square. Legs stout, moderately long. Abdomen full, at base as broad as the cephalothorax, broadening slightly behind, fully rounded, the first segment about one-third the length of the others, which are equal."

Although this description may have been sufficient when it was published to differentiate a fossil genus, unfortunately everything that is said in describing it might equally apply to every known living species.

Petrunkevitch (1913) restudied the type of Scudder's *punctulata*, which is now in the United States National Museum (No. 37971), and he published both figures and photographs of the same. This author considered the genus good and bases his conclusions on the characters of the second leg. This leg has been represented as being composed of only three segments beyond the femur and to be terminated with a pair of claws. In other words this part of the leg is supposed to be composed of a normal patella, a short tibia and a very short, fused basitarsus and tarsus. Our living specimens have this part of the leg composed of a patella, a long tibia, a long basitarsus and a long five-segmented tarsus. Furthermore, in all the living Ricinulids the second legs are much the longest of all pairs. As Scudder's type has been interpreted, this pair is supposed to be much shorter than either the third or fourth pair.

In order to get further evidence upon the nature of the segmentation of leg II of fossil forms the writer worked out the second leg of a specimen of *Curculioides ansticii* Buckland. The patella and the more proximal segments were already exposed and distinct, and by removing the overlaid material the full length of the tibia was revealed, very definitely stained brown by iron deposit. Using this preparation for comparison with the type of Scudder's *punctulata*, it could be seen that what had been considered as tibia and fused basitarsus (metatarsus) and tarsus was in reality one segment, the tibia. There is a suture-like structure in this part of the leg of Scudder's type, but an examination of it under the binocular microscope shows that it only represents what was a crack in the integument of the fossil specimen.

But how about the claws at the end of leg II in Scudder's type? There is a curved line impressed in the clay ironstone

that is quite suggestive of the imprint of a claw or claws. But do they really represent impressions of these structures? The writer is of the opinion that they do not for two reasons:

(1). They do not occur at the right place in the leg, counting the segments from the base toward the tip.

(2). Tarsal claws are unknown in all of the known Palaeozoic spider fossils, of which there is a large number of specimens. In all of these not a single tarsus has been found terminated with claws.

If we reject, then, the characters of the legs as given for *Polyochera*, what is to become of the genus? Fortunately the coxæ give us good generic characters. In this genus, and also in *Curculioides*, the second pair of coxæ are short and triangular and are separated from each other mesially. In our living Ricinulids these coxæ are similar to those of the third pair, being long and broadly matching each other on the median line.

The four genera of Ricinoididæ may be separated by means of a key as follows:

KEY TO THE GENERA OF LIVING AND EXTINCT RICINULEI.

A. Second coxae subtriangular and not meeting on median line, Palaeozoic genera
  B. Dorsum of abdomen divided into distinct tergites by transverse sutures.....**Polyochera** Scudder.
  BB. Dorsum of abdomen without transverse sutures, **Curculioides** Buckland.
AA. Second coxae broad, platelike and coming together on the median line. Recent genera, represented only by living species.
  B. Movable digit of chelicera apposed by a large and a small fixed digit; fourth segment of tarsus II longer than fifth. Ethiopian species.....(Cryptostemma Guérin). **Ricinoides**, new name.
  BB. Movable digit of chelicera apposed by a single, large, fixed digit; fourth segment of tarsus II shorter than fifth. Neotropical species.....**Cryptocellus** Westwood.

The Genus **Cryptocellus** Westwood.

All of our living American Ricinulids go into the genus *Cryptocellus* Westwood. It is unfortunate that in no single instance have both sexes been collected of a single one of the included species; yet the writer has on hand no less than seven specimens of one species. The characters of this genus have already been given.

KEY TO THE SPECIES OF CRYPTOCELLUS.

(The Living American Species of Ricinulei).

A. Length of body over 7.5 mm.; integument with but few tubercles, but provided with pits.....**C. magnus,** new species.
AA. Length of body less than 6 mm.; integument tuberculate.
B. Last segment of tarsus II equal in length to all the other segments, **C. manni,** new species.
BB. Last segment of tarsus II not longer than third and fourth together.
C. Movable digit of chelicera with a much enlarged tooth near the base of the row. Not reported from Brazil.
D. Upper posterior margin of first postabdominal segment deeply notched on median line, **C. emarginatus,** new species.
DD. Upper posterior margin of first postabdominal segment not notched.....**C. barberi,** new species.
CC. Movable digit of chelicera without such a tooth. Brazilian species.
D. Hood but slightly broader than long, and scarcely lobed ventrally.....**C. foedus** Westwood.
DD. Hood about one and a half times as broad as long, and distinctly lobed ventrally, **C. simonis** Hansen & Sörensen.

DESCRIPTIONS OF SPECIES.

Technical descriptions are here given for four new species. No complete descriptions can be given for the two that have been previously distributed. However, notes have been taken concerning them from the excellent synopsis of Hansen and Sörensen (1904). It should be stated that each of these two species is represented by a single specimen.

Cryptocellus magnus, new species.

(Plate I).

FEMALE.

Cephalothorax longer than broad and irregularly clothed with scant pubescence above. Integument pitted instead of being tuberculate. Above each coxa II on each side of the cephalothorax is a lighter, outwardly convex area, simulating the cornea of an eye.

Hood considerably broader than long, swollen distally and clothed in front with fine hair-like setæ.

Cheliceræ completely hidden in the single dry-mounted specimen.

Pedipalps reddish brown, much lighter in color than the body. First, or fixed, segment of pedipalps plate-like; second very short, swollen distally; third broader than long and longest along front aspect; fourth about three times as long as third and curving backward very strongly along its distal half; fifth almost as long as the second, third and fourth combined and terminated by a short, fixed claw; sixth segment, or claw, longer than fixed claw of fifth segment.

First pair of legs the shortest of all pairs; coxa triangular and not meeting its fellow on the median line; trochanter as broad as long; femur over twice as long as trochanter and excavated below on its distal half; patella but slightly longer than broad and somewhat pedicellate; tibia one and a half times as long as patella and excavated ventrally on its distal two-thirds; basitarsus slightly longer than tibia, curved upward and with a few tubercles on upper surface; tarsus but slightly longer than broad, swollen.

Second pair of legs the longest, sharply bent, or kneed, at the junction of femur with patella; basitarsus curved upward, as long as tarsus; five-segmented tarsus with last segment equal in length to second, third and fourth put together. The second pair of legs has some spine-like tubercles, chiefly on the ventral surfaces.

Third pair of legs slightly shorter than the fourth; the two trochanters subequal; tibia and basitarsus of about equal length.

Fourth pair of legs next to second in length but much shorter than this pair; two trochanters subequal; tibia and basitarsus of about equal length, the former excavated below for almost its entire length.

Abdomen proper almost black, more or less sparsely clothed with minute, hair-like setæ and without tubercles, but instead provided with pits. There is a very definite row of these pits on the dorsum along the suture between the first and second visible tergites, also a row of smaller pits laterally, parallel to the lateral margins of the body on the second and third visible tergites.

Postabdomen represented by the last three abdominal segments, its second segment being completely contained by the first, and the third by the second. First, or outer, segment as broad as long, swollen, and with an even posterior border. No comb of teeth on second segment.

Total length of body in natural position, 7.80 mm.; length of cephalothorax, 2.20 mm., width, 2.10 mm.; length of abdomen exclusive of postabdomen, 5.10 mm., width, 3.10 mm.

Type locality. Cincinatti, Colombia.

Type. Cat. No. 955, U. S. N. M.

Described from a single female collected at type locality, 1924, by Dr. W. M. Mann. Although this species is much smaller than some of the fossil forms, it is much larger than any of the other living American species. Not only is *magnus* very distinct among the American Ricinulids on account of its size but also because of the paucity of tubercles on the integument, there being but few of these, which are confined almost exclusively to the under surfaces of the legs. Also this species is peculiar in having pits on the dorsal surface of the body. These may be regarded, in a way, as taking the place of the tubercles.

Cryptocellus manni, new species.
(Plate II, Fig. 2; Plate III, Fig. 5).

FEMALE.

Cephalothorax of about equal length and breadth, being broadest near the posterior margin. It is adorned dorsally with groups of tubercles (Pl. II, Fig. 2) and clothed with fine hair-like setæ. Dorsal tubercles grouped as follows: There is a band of tubercles along the posterior margin, an irregular row of tubercle groups along the median line, an irregular row of tubercle groups along each lateral margin, and between these some irregularly placed groups in the posterior two-thirds of cephalothoracic area.

Hood (Pl. III, Fig. 5) considerably broader than long and very slightly lobed; clothed with short, hair-like setæ and basal half adorned with flattened, circular tubercles that are grouped laterally and along the median line.

Chelicerœ powerful, the movable arm surpassing the fixed one and provided with six teeth, the basal one of which is much larger than the others; fixed arm with distal tooth much the largest.

Pedipalps of usual shape; basal segment well studded with tubercles; each of the other segments with a few tubercles. Movable arm of pincers with about a dozen very low oval teeth; fixed arm with 6–7 larger teeth, the most proximal being the largest and almost square in outline.

First pair of legs the shortest, reaching to about the middle of the tibiæ of second legs; basitarsus curved; tarsus scarcely half as long as basitarsus and much swollen dorsally.

Second pair of legs almost twice as long as the first pair; coxa not narrowed toward median line and with a row of tubercles around its anterior, inner and posterior margins; femur and basitarsus curved; tarsus about equal to basitarsus, each successive segment of the same being longer than its proximal predecessor and the last being equal to the first four.

Third legs longer than the first or fourth; coxa wedge-shaped, its width proximally being equal to about one-half the width at distal end; anterior, inner and posterior borders of coxa with a row of tubercles; tarsus slightly longer than basitarsus, last segment being the longest and swollen.

Fourth legs between the first and third in length; coxa similar to coxa of leg III, but shorter and broader; tarsus fully as long as basitarsus and with its distal segment the longest and swollen.

Abdomen proper with tergites well separated and provided with groups of tubercles which are grouped largely about the margins. Most of these groups are circular in shape. In addition to these tubercles the abdomen is well provided with short setæ.

Postabdomen as broad as long, the second segment being contained in the first and the third in the second. The second postabdominal segment bears a comb of four flattened, subspatulate setæ. These setæ are so broad that they almost touch each other.

Total length of body in natural position, 4.95 mm.; length of hood, 0.93 mm., width, 1.27 mm., length of cephalothorax, 1.30 mm., width, 1.10 mm.; length of abdomen exclusive of postabdomen, 3.50 mm., width, 2.40 mm.; length of first segment of postabdomen, 0.50 mm., width, 0.52 mm.

Type locality. Cincinatti, Colombia.

Type. Cat. No. 996, U. S. N. M.

Described from a single female taken at the type locality, February, 1924, by Dr. W. M. Mann, for whom the species is named. Two of the other species described in this paper have the postabdominal comb, but in them the spines are not flattened as they are in *manni*. This species is distinct, also, in the manner of distribution of the tubercles on the integument.

Cryptocellus emarginatus, new species.
(Plate III, Fig. 7).

Cephalothorax almost as broad as long, completely studded above with round tubercles and sparsely invested with short, inconspicuous setæ.

Hood much broader than long, entirely studded above with tubercles and clothed with hair-like setæ of varying lengths. It is not lobed.

Cheliceræ stout; movable arm sickle-shaped, with 8–10 teeth, no one of which is markedly larger than any of the others; fixed arm doubly curved, distal half being toothless, while basal half bears four teeth, the most distal being the largest.

Pedipalps of the usual shape; first, or fixed, segment broader than long, with its inner half studded with tubercles; pincers at distal end rather sharp; movable arm more strongly curved about its middle than elsewhere, inner margin with minute sharp teeth, more numerous toward the base; fixed arm with 4–5 much larger teeth.

First pair of legs reaching to about the middle of the tibiæ of the second pair; coxa long and wedge-shaped and studded with tubercles; tibia swollen toward its base, shorter than basitarsus; basitarsus curved, well studded with short, spine-like tubercles dorsally; tarsus very short, subglobular.

Second pair of legs much the longest, as usual; coxa long for its width, broadest near distal end, posterior border broadly emarginate, most of tubercles arranged on the margins; trochanter slightly longer than broad, but broader than femur; basitarsus almost straight, longer than tarsus and studded with spine-like tubercles; tarsus with each succeeding segment longer than the preceding, the last one being shorter, however, than the third and fourth taken together.

Third pair of legs reaching beyond the base of basitarsus; coxa strongly outwardly curved along front margin near the distal end, with tubercles arranged chiefly along the margins; basitarsus and tarsus subequal, the last segment of the latter swollen and peculiar in being diamond-shaped, (Plate III, Fig. 7).

Fourth pair of legs about as long as third pair; coxa about as long as coxa of third legs and studded with tubercles in much the same way; basitarsus longer than tarsus; last segment of tarsus swollen.

Abdomen proper oval, all tergites fairly evenly studded with tubercles; central section of tergite of second visible segment produced at anterior corners; lateral sections of first tergite small, almost circular.

Postabdomen about as broad as long and with segments arranged in their usual positions; first segment much swollen toward its base and deeply notched on its posterior border at the upper median line; second segment long and narrow, being almost twice as long as wide, and less than half as wide as first segment, with comb of four spines; third segment very small, less than half as long as second segment and about half as wide.

Total length of body in natural position, 3.85 mm.; length of hood, 0.51 mm., width, 0.83 mm.; length of cephalothorax, 1.45 mm., width, 1.33 mm.; length of abdomen exclusive of postabdomen, 2.40 mm., width, 2.20 mm.; length of first segment of postabdomen, 0.46 mm., width, 0.40 mm.

Type locality. Navarro Farms, Costa Rica.

Type. Cat. No. 997, U. S. N. M.

Described from a single specimen (adult female?) taken at type locality, March 19, 1924, by Dr. W. M. Mann. This species is distinct in the shape of the last segment of tarsus III and in having the tubercles distributed over practically all the sclerites of the body.

Cryptocellus barberi, new species.
(Plate II, Fig. 3; Plate III, Figs. 4, 6).

FEMALE.

Cephalothorax distinctly longer than broad, front margin about straight, posterior margin outwardly rounded. Above, the cephalothorax is completely studded with circular tubercles and clothed sparingly with short, hair-like setæ.

Hood (Pl. III, Fig. 4) very much broader than long, clothed with hair-like setæ of varying lengths and provided on each side at the base with a cluster of low, cylindrical tubercles.

Cheliceræ (Pl. III, Fig. 6) stout; movable arm surpassing fixed one, provided with 6–7 teeth, the second one from the base being the largest; fixed arm strongly curved distally and provided with 5–6 teeth, the distal one being much the largest; setæ on chelicera long, straight and minutely pectinate.

Pedipalps rather slender; basal segment considerably longer than broad and with inner half studded with tubercles; second segment slightly longer than broad; third segment longer than usual and somewhat pedicellate; pincers small, movable arm almost twice as long as fixed one, both arms with small teeth.

First pair of legs reaching almost to the tip of tibia of second pair; coxa triangular and studded with tubercles; tibia straight, much longer than patella; basitarsus shorter than tibia; tarsus about three-fourths as long as basitarsus.

Second pair of legs of usual length; coxa very broad and of about the same width throughout, studded with tubercles except for a middle area; trochanter very slightly broader than femur; basitarsus about equal to tibia and studded throughout with tubercles; tarsus longer than basitarsus, its last segment being almost equal to segments 3 plus 4.

Third pair of legs about equal to fourth; coxa wedge-shape and with most of the tubercles arranged along the margins; tibia much longer than patella, slightly swollen; basitarsus slightly curved, equal to tibia; tarsus slightly longer than basitarsus, third segment the shortest, fourth the longest.

Fourth pair of legs the weakest; coxa broader and shorter than coxa III; each trochanter longer than broad; femur about straight; patella short and swollen; tibia stout and straight; basitarsus equal to tibia in length but more slender; tarsus slightly longer than basitarsus, its distal segment being almost equal to third and fourth taken together.

Abdomen proper (Pl. II, Fig. 3) with strongly rounded sides, the outer margins of the lateral plates being rounded to conform to lateral margins. Tergal plates studded with tubercles as shown in Figure 3, Plate II.

Postabdomen about as broad as long and strongly swollen in the middle; outer, or first, segment with basal half studded with tubercles, posterior border not emarginate dorsally; second segment less than half as broad as the first and with comb of four peg-like setæ; third segment cone-shaped, almost as broad as long.

Total length of body in natural position, 4.50 mm.; length of hood, 0.47 mm., width, 0.76 mm.; length of cephalothorax, 1.47 mm., width, 1.30 mm.; length of abdomen exclusive of postabdomen, 2.80 mm., width, 1.70 mm.; length of first segment of postabdomen, 0.43 mm., width, 0.40 mm.

Type locality. Near Livingston, Guatemala.

Type. Cat. No. 998, U. S. N. M.

Described from seven specimens, including an adult female taken at La Ceiba, Honduras, 1920, by W. M. Mann, and six individuals taken at type locality by H. S. Barber. The individuals taken by Mr. Barber, for whom the species is named, include adult females and nymphs and were taken, according to him, "In leaf litter on steep talus between limestone cliff and Rio Dulce, about three miles from Livingston, Guatemala, May, 1906." Mr. Barber states that the individuals moved about slowly and were all taken in an area of a few square yards.

The specimens from Guatemala are in an excellent state of preservation, notwithstanding the fact that they were taken over twenty years ago. This will allow work to be done on the internal anatomy of these arachnids, concerning which nothing is known. In fact the writer has already sacrificed one individual and has learned something of the nervous and digestive systems.

There is a very large central nerve mass or brain located ventrally in the anterior region of the cephalothorax, and this central ganglion sends large nerves to the cheliceræ and legs and smaller ones to certain other structures.

A feature of importance in regard to the digestive system is the great development of the liver sacs. These structures are by far the most conspicuous of any in the abdomen. They are caeca of large diameter and with granular cells and fill up most of the space above and to the sides of the almost straight alimentary canal.

The gut proper enlarges into sac-like proportions in front of the small rectum. The latter passes directly through the last segment of the small postabdomen and empties through a slit-like, chitin-rimmed anus at the tip. Hansen and Sörensen (1904) are quite right in stating that the anus is situated at the end of the inner (last) segment of the postabdomen. The anal slit, in fact, may be seen in undissected specimens by viewing the postabdomen directly from behind in strong light with the binocular microscope. The morphology of this species will be worked out at some future date. It was thought proper to add this much in giving notes on our only American species of Ricinulei that is known from more than one specimen.

Cryptocellus foedus Westwood.

FEMALE.

This species described by Westwood in 1874 is known only from a single female. The specimen was collected by Bates (1861) in the Province of Amazonas, Brazil. Hansen and Sörensen (1904) have given a good description of it accompanied by excellent figures. From their work it is learned that this species is very much like *C. barberi*, new species, but differs from *barberi* in a number of respects. In *foedus* there is no enlarged tooth at the base of the row on the movable arm of the chelicera; in *foedus* the hood is slightly bilobed and studded

over most of its external surface with tubercles, while in *barberi* there is no indication of the hood being bilobed, and the tubercles are all confined to the upper corners; in *foedus* the tergal plates of the abdomen are about evenly studded with tubercles, while this is not true of *barberi*.

The measurements given for *foedus* by Hansen and Sörensen follow:

> "Length of body, 4.9 mm.; length and width of cephalothorax, 2.0 mm.; length of abdomen, 3 mm.; palpi, 3.7 mm.; legs, I, 4.6 mm.; II, 7.7 mm.; III, 5.2 mm.; IV, 5.5 mm."

The species is said to be black above and fuscus ferrugineous below; dorsum of body densely and finely granular; and the cucullus to be a little longer than its width at the base.

Cryptocellus simonis Hansen and Sörensen.

MALE.

The single male specimen upon which the description of this species is based is the only male Ricinulid to be taken in the New World. Fortunately for science it has been well described by Hansen and Sörensen and excellently figured by Hansen. *C. simonis* was taken in the same upper Amazon region that *C. foedus* came from, and is a species apparently most closely related to *foedus*. Unfortunately, however, from the standpoint of comparison of the two, the same sex is not known for both of them.

C. simonis is said to differ from *foedus* particularly in the shape of the hood, or cucullus. The hood of *simonis* is, according to Hansen and Sörensen, broader in proportion to its length, is distinctly bilobed, and has fewer tubercles. In the specimen described the dorsal sclerites of the abdomen have grown almost together.

The modified third legs of the male are more extreme in their adaptation than in the African Ricinulids. The basitarsus constitutes a subspherical bulb with a rather large opening; the first segment of the tarsus is reduced posteriorly and in front expanded into a leaf-like process; the second segment of the tarsus is lengthened and expanded in front into a leaf-like process joined with that of the first segment; the last two tarsal segments are not modified.

The dimensions of *C simonis* given by Hansen and Sörensen are:

> "Length of body, 5.3 mm.; length of cephalothorax, 2.2 mm.; width of cephalothorax, 2.0 mm.; length of abdomen, 3.1 mm.; palpi, 3.2 mm.; legs, I, 5.4 mm.; II, 9 mm.; III, 5.8 mm.; IV, 6.3 mm."

The single specimen was taken in the Province of Amazonas, Brazil.

A List of the Known Species of Living Ricinulids, Their Distribution and the Number of Specimens Taken.

Ricinoides, new name.

1.	*R. westermanni* (Guérin)	Togo	1♂, 1 jouv.
2.	*R. afzelii* (Thor)	Sierra Leone	2 ♀'s.
3.	*R. karschii* (Hansen and Sörensen)	Kamerun and Congo	2 ♂'s, 2 ♀'s.
4.	*R. crassipalpe* (Hansen and Sörensen)	Kamerun	2 jouv.
5.	*R. plebejum* (Hansen and Sörensen)	Togo	1 jouv.
6.	*R. sjöstedtii* (Hansen and Sörensen)	Kamerun	6 (♂'s, ♀'s, jouv.)

Cryptocellus Westwood.

1.	*C. foedus* Westwood	Brazil	1 ♀.
2.	*C. simonis* (Hansen and Sörensen)	Brazil	1 ♂.
3.	*C. magnus*, new species	Colombia	1 ♀.
4.	*C. manni*, new species	Colombia	1 ♀.
5.	*C. emarginatus*, new species	Costa Rica	1 (♀?).
6.	*C. barberi*, new species	Guatemala and Honduras	7 (♀'s and jouv.)

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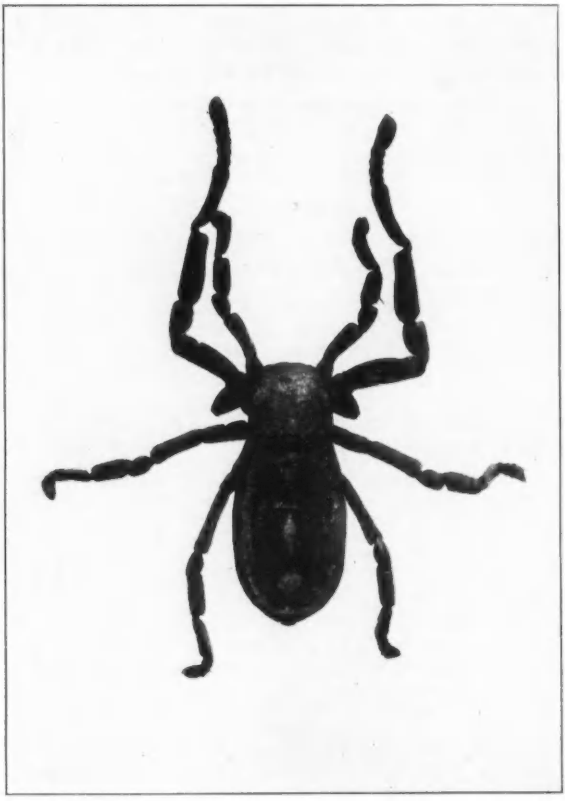

Fig. 1. *Cryptocellus magnus*, new species.
Dorsal view of female, × 5.

(Photograph by J. C. Pratt, of the Bureau of Entomology.)

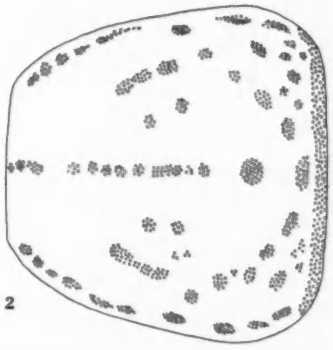

Fig. 2. *Cryptocellus manni*, new species.
Dorsal view of cephalothorax (hood detached) showing arrangement of tubercles, but not showing setæ, × 38.

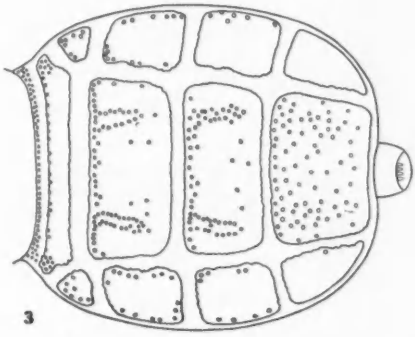

Fig. 3. *Cryptocellus barberi*, new species.
Dorsal view of abdomen showing tergites and chitinous tubercles, but not showing setæ, × 38.

(Drawings by H. E. Ewing.)

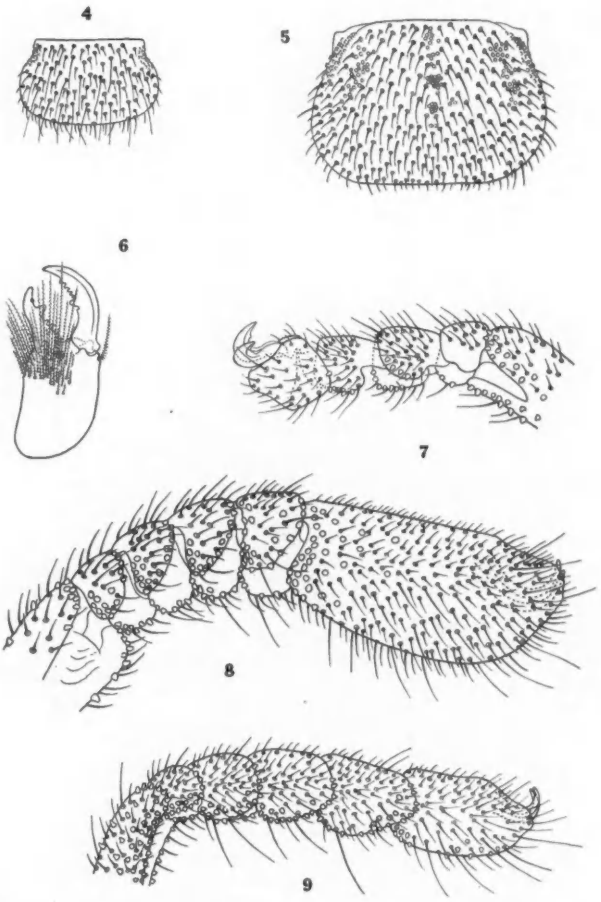

Fig. 4. *Cryotocellus barberi*, new species. Front view of hood, × 38.
Fig. 5. *Cryptocellus manni*, new species. Front view of hood, × 38.
Fig. 6. *Cryptocellus barberi*, new species. Ventral view of left chelicera, × 50.
Fig. 7. *Cryptocellus emarginatus*, new species. Dorsal view of left tarsus III, × 50.
Fig. 8. *Cryptocellus manni*, new species. Dorsal view of right tarsus II of female, × 50.
Fig. 9. *Cryptocellus emarginatus*, new species. Dorsal view of right tarsus II of female, × 50.

(Drawings by H. E. Ewing.)

ABSOLUTE HUMIDITY AS A FACTOR IN INSECT COLD HARDINESS WITH A NOTE ON THE EFFECT OF NUTRITION ON COLD HARDINESS

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Formerly National Research Fellow in Zoology, 1925-27

ABSTRACT.

In both eggs and larvæ of *Hemerocampa leucostigma* Smith and Abbot, cold hardiness can be expressed by the equation

$$T_1 = K\frac{1}{H_a}$$

where T_1 = survival temperature in degrees centigrade (or cold hardiness to the intensity factor).

H_a = absolute humidity in millimeters of vapor pressure.
K_0 = constant for eggs = 44
K_1 = constant for 1st instar larvæ = 41.8
K_2 = constant for 2nd instar larvæ = 37.4
K_3 = constant for 3rd instar larvæ = 34

Larvæ from cold hardy eggs tend to be more cold hardy than larvæ from non-cold hardy eggs. Larvæ of each succeeding stadium tend to be less cold hardy than the one preceding.

In the larvæ of the Japanese beetle, *Popillia japonica* Newman, absolute humidity is correlated with cold hardiness to the intensity factor of low temperature. The adult, although a summer stage, is more cold hardy than the 3rd instar larva, and the 3rd instar larva is more cold hardy than the first. Absolute humidity does not play as important a part in cold hardiness of the adult as for the larvæ. In the Japanese beetle larvæ starvation at first increases, later decreases cold hardiness. Type of food affects degree of cold hardiness.

INTRODUCTION.

The environmental factor of absolute humidity, or the total amount of atmospheric moisture present in the air at a given temperature has been little used in ecological work. The literature on the effects of relative humidity,

$$\frac{\text{moisture present in air}}{\text{moisture air can hold at a given temperature,}}$$

is voluminous. In general, low relative humidity in both plants and animals is associated with increased cold hardiness.

This paper is one of a number of studies by the author on factors associated with, or producing cold hardiness, especially in organisms exposed to low temperature extremes in their normal habitat. The eggs of the white marked tussock moth, *Hemerocampa leucostigma* Smith and Abbott, were studied in 1926-1927 and in 1927-1928. Eggs of this species can be obtained in large quantities, even in cities, where they occur on trees, telephone poles, and in the crevices of stone walls. From 150-700 eggs are laid in one cluster, which is generally covered by a coarse cocoon. The tussock moth over-winters in the egg stage.

The Japanese beetle over-winters in the larval stage, about 97% in the 3rd; about 3% in the 2nd instar. The adult appears from early summer till early fall, and in the vicinity of Philadelphia can be procured in large quantities.

TABLE I.

TEMPERATURE INSIDE AND OUTSIDE A TUSSOCK MOTH EGG COCOON.

Outside Cocoon	Inside Cocoon
25. °C.	24.9°C.
20. °C.	20. °C.
12.5°C.	12.5°C.
10. °C.	10. °C.
5.6°C.	5.6°C.
4. °C.	4.1°C.
0. °C.	0. °C.
—12. °C.	—12. °C.
—14. °C.	—14. °C.
—17. °C.	—17. °C.
—20. °C.	—20. °C.

COLD HARDINESS IN TUSSOCK MOTH EGGS.

At the end of the first year the survival temperature of 600 eggs had been tested. They exhibited no apparent periodicity. Their cold hardiness is not a linear function of temperature. At a given temperature cold hardiness was found to be correlated with relative humidity; the greater cold hardiness being associated with the lowest relative humidity. Work was continued on these eggs a second year, when over 1500 eggs were frozen, bringing the total number of determinations to 2100.

The amount of insulation offered by the cocoon covering tussock moth eggs was determined by inserting one thermo-

couple inside the cocoon and another outside the cocoon. There was no appreciable difference or lag between temperature inside and outside the cocoon. The results of a series of studies made to determine the insulating properties of cocoons are shown in Table I. Tussock moth eggs therefore form a group exposed to the extremes of the environmental temperature. Eggs were collected from September to June in 1926-1927 and 1927-1928.

Eggs were placed in small chambers in which the humidity was controlled by H_2SO_4, according to the method of Baumberger (1914). Headlee's method (1917) of using supersaturated solutions of different salts was also used. Temperature

TABLE II.

Effect of Dehydration on Viability of Tussock Moth Eggs.

Temperature	Relative Humidity	Number of Eggs Exposed	Number Hatched	Per cent Hatched
20°C.	100	250	215	86.7%
	80	200	187	93.5%
	50	200	99	49.5%
10°C.	100	250	218	87.2%
	80	300	276	92.2%
	50	250	217	86.8%
0°C.	100	250	203	81.2%
	80	200	183	91.5%
	50	200	160	80 %

was controlled within ± 1.0°C. The methods for controlling relative humidity have their limitations, especially in small chambers with very slow or very little circulation. However the methods gave comparable results which could be repeated.

Eggs from each cocoon were divided into two sets (1) for cold survival tests, and (2) as controls. Hatching was the final test of viability. After some experience it was possible to tell the condition of the egg even before hatching. Healthy eggs are firm, white and almost spherical. Eggs which do not hatch are somewhat darker and often have depressions in them. The effect of a series of temperatures and relative humidities on the hatchability of eggs is shown in Table II. Low relative humidity does not affect viability except at high

temperatures. At +20°C. with 50% relative humidity about half the eggs hatched.

Generally eggs do not hatch when kept in a dry atmosphere except on subsequent soaking. All eggs in these experiments were soaked to facilitate hatching. Soaking introduces an additional factor, which is offset however by the hastened process of hatching, thus eliminating additional growth and time factors.

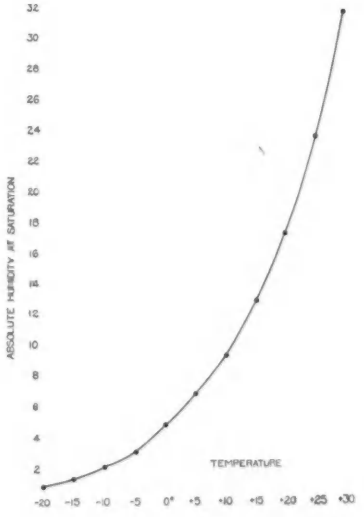

Fig. 1. Absolute humidity at saturation expressed in millimeters vapor pressure plotted against temperature in degrees centigrade.

As was stated above, ordinary eggs, kept at a low relative humidity do not hatch. Hatching of eggs that were dehydrated occurred once during the second years' work, when a lot of 100 eggs being dehydrated over $CaCl_2$ hatched. Fifty of these larvæ were tested for cold resistance, but none of them were able to withstand temperatures lower than −2.°C. Both the eggs and larvæ of this lot were exceptional, for in all other cases eggs capable of resisting low humidities produced cold hardy larvæ. The $CaCl_2$ was tested and found to be in good condition, thus showing that the eggs had actually been exposed to dehydrating action. The only apparent explanation is that dehydration carried too far does not produce cold hardy larvæ.

Since temperature effect alone could not explain differences in cold hardiness between tussock moth eggs, and since their cold hardiness bore a relationship to both temperature and relative humidity, absolute humidity was thought to be the key to cold hardiness. Absolute humidity at saturation forms a logarithmic curve which rises slowly at low and very rapidly at high temperatures, (See Fig. 1). Similar curves are produced at other relative humidities than saturation. The cold hardiness of the 600 tussock moth eggs tested in 1926-1927, and

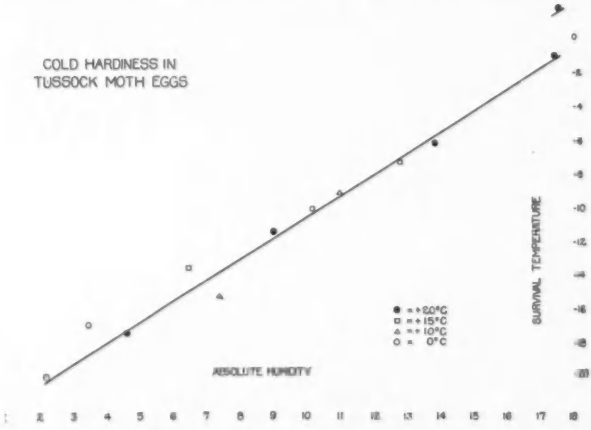

Fig. 2. Cold hardiness in tussock moth eggs as measured by survival temperature. Each reading represents an environmental temperature at which eggs were kept, at a given absolute humidity. With each environmental temperature, three different humidities were used.

of the 1500 tested in 1927-1928 is shown in Fig. 2 and Table III. Cold hardiness bears an inverse relationship to absolute humidity, the greater cold hardiness being associated with the lowest absolute humidity, regardless of temperature. The most cold-hardy egg thus far tested survived −28°C. Before using this figure as a cold hardiness limit for the species it must be remembered that this figure would hold only for eggs taken from the Philadelphia region or from similar climatic conditions. It was found in the case of the oak-borers, *Synchroa punctata*, and *Dendroides canadensis*, that specimens from Minnesota were more cold hardy than those from Pennsylvania. In Minnesota the most cold hardy oak borer survived −50°C., in Pennsylvania −28°C.

Cold Hardiness in Tussock Moth Larvæ.

Tussock moth larvæ of the 1st, 2nd, and 3rd instars of the over-wintering generation have also been studied. The larvæ can easily be reared on lettuce. Since these larvæ can be somewhat poisonous, especially to one handling them over long periods of time, they were transferred with brushes, and precautions taken to avoid touching either the larvæ or the hairs which they shed.

TABLE III.

Cold Hardiness in Tussock Moth Eggs.

Environmental Temperature	Survival Temperature	Relative Humidity in %	Absolute Humidity
20°C.	1.5± .5	100	17.5
	6.1±1.3	80	13.9
	11.5±2.4	50	9.
15°C.	7. ±1.7	100	12.8
	10. ±2.25	80	10.2
	13.5±3.1	50	6.5
10°C.	11. ±2.3	100	9.2
	13.3±3.2	80	7.4
	16.5±5.6	50	4.6
0°C.	16.5±4.1	100	4.6
	17. ±3.	80	3.5
	20. ±5.3	50	2.2

Larvæ of the 1st instar of the over-wintering generation exhibited no marked periodicity in cold hardiness. The conditions under which they were reared in this experiment are admittedly highly artificial, and may fail to reflect a periodicity which would appear in specimens living out of doors at a variable temperature.

Larvæ hatching from cold hardy eggs tended to be cold hardy, but less so than the eggs. Tussock moth larvæ from eggs kept at 0°C. were more cold hardy than those from eggs kept at 20°C. The most cold hardy 1st instar larvæ thus far discovered survived −25°C.; the most cold hardy egg −27.5°C. Cold hardiness of the 1st instar larvæ kept at different environmental temperatures is shown in Table IV. As in the eggs, cold hardiness is a linear function of absolute humidity.

The ratio of cold hardiness in eggs to the cold hardiness of their larvæ could be tested for viable eggs only. There is no way to determine the possible cold hardiness of larvæ of non-cold hardy eggs which died during experimentation. This

TABLE IV.

COLD HARDINESS OF FIRST INSTAR TUSSOCK MOTH LARVÆ.

Environmental Temperature	Survival Temperature	Relative Humidity in %	Absolute Humidity
20°C.	1.4± .6	100	17.5
	4. ±1.1	80	13.9
	9. ±1.7	50	9
10°C.	9.5±1.8	100	9.2
	11. ±3.0	80	7.4
	14. ±4.5	50	4.6
0°C.	15. ±4.3	100	4.6
	16. ±2.8	80	3.5
	17.5±4.9	50	2.2

limitation of the material was in part compensated by obtaining the survival temperatures of larvæ of moderately cold hardy eggs and comparing it with the survival temperatures of larvæ from eggs of greater cold hardiness. The relationship of cold

TABLE V.

EFFECT OF COLD HARDINESS OF EGGS OF TUSSOCK MOTH ON LARVÆ SUBSEQUENTLY HATCHED FROM THEM.

Survival Temperature of Eggs		Survival Temperature of Larvæ	
Mean	Minimum	Mean	Minimum
—20 ±4.5	—27.5	—19 ±3.2	—25.0
—15.4±4.3	—23.1	—14.5±4.5	—21.3
—10 ±2.25	—15.1	— 8 ±3.	—13.7
— 5 ±1.2	— 8.4	— 5 ±1.3	— 7.2

hardiness of eggs to cold hardiness of larvæ subsequently hatched from them is shown in Table V. Both maximum and average cold hardiness are greater in the eggs than in the 1st instar larvæ.

The 1st instar larvæ were fed on lettuce and kept at temperatures of 0°C., 10°C., 15°C., and 20°C. Zero temperatures were maintained by keeping the larvæ in individual vials in thermos bottles filled with water and ice mixtures. Survival temperatures of the 2nd instars of these larvæ, together with the absolute humidities are shown in Table VI. For the 2nd instar larvæ of the over-wintering generation, cold hardiness, both maximum and average, is slightly less than that of the 1st instar larvæ. Cold hardiness is again a linear function of absolute humidity.

TABLE VI.

COLD HARDINESS OF SECOND INSTAR LARVÆ OF THE TUSSOCK MOTH.

Environmental Temperature	Absolute Humidity	Survival Temperature	
		Mean	Minimum
20°C.	17.5	— 1. ± .7	— 5.6
	13.9	— 3.1±1.7	— 7.5
	9	— 8. ±2.5	—11.
15°C.	12.8	— 5. ±1.5	—10.3
	10.2	— 7.9±2.1	—11.8
	6.5	— 8.8±3.4	—12.4
10°C.	9.2	— 7.2±2.3	—10.5
	7.4	—10.3±3.7	—12.7
	4.6	—12.9±4.1	—14.
0°C.	4.6	—14.1±5.	—19.4
	3.5	—15.7±4.6	—21.
	2.2	—17. ±2.3	—23.

Larvæ were reared to the 3rd instar and again tested as for the 2nd instar. These results are given in Table VII. The most cold hardy larvæ survived −17.8°C. and the least cold hardy −1.2°C. Thus the 3rd instar larvæ were less cold hardy than the 2nd.

Experiments on the 4th and 5th instars, while not so extensive as those made on the 1st, 2nd, and 3rd, indicate that the 4th instar is less cold hardy than the 3rd, and the 5th is less cold hardy than the 4th. Maximum and average values of survival temperatures for 4th instar larvæ kept at 0°C. were −15°C. maximum, and −11.5°C., mean; for the 5th instar, −13°C., maximum, and −8.5°C., mean. Each of these values is based on 100 larvæ. Cold hardiness also appears to be a linear function

of absolute humidity in these as in the previous stages. Cold hardiness has not been determined for the pupa and the adult.

In the tussock moth no one stage exhibited periodicity in cold hardiness. If both egg and larval stadia are taken as a whole the organism can be said to be periodic, since each succeeding stage in the life history is less cold hardy than the one it follows. Even at constant temperature the individual larva loses cold hardiness with each molt. When the life history of the insect is considered it will be seen that with an insect hatching in the spring, the later stages normally appear in warmer weather than the earlier. Thus the older tussock moth larvæ are really late spring or early summer forms.

TABLE VII.

COLD HARDINESS OF THIRD INSTAR LARVÆ OF THE TUSSOCK MOTH.

Survival Temperature		Environmental Temperature	Absolute Humidity
Mean	Minimum		
—15.5±1.5	—17.8	0°C.	2.2
—12.3±2.2	—15.2	0°C.	4.6
— 4. ±1.3	— 6.	15°C.	12.8
— 2. ± .8	— 5.4	20°C.	13.9

Cold hardiness when measured by maximum cold hardiness for a stage held at the temperatures and humidities used, decreased with each succeeding stage. Mean survival temperature of eggs kept under conditions of 20°C. and 100% relative humidity (17.5 mm. absolute humidity) was −1.5 ±.5°C.; mean survival temperature for 1st instar larvæ, was −1.4±.6°C.; for the 2nd instar −.8 ±.3°C.; for the 3rd −.5 ±.2°C. For this high temperature and humidity (both relative and absolute) the difference between cold hardiness of eggs and 1st instar larvæ is not significant. For lower temperatures and lower humidities differences between successive stages are larger. It may be that at as high a temperature as 20°C. and humidity at saturation (100% relative humidity) whatever periodicity is inherent in the organism is concealed, or may actually be removed by the environment. At 20°C. and 80% relative humidity, significant differences in cold hardiness did appear between each stage in the life history of the tussock moth. Tussock moths can be reared from egg to pupa at +10°C.,

+15°C., or +20°C. Eggs can be kept at 0°C. for 6 months and still retain their viability. First instar larvæ can survive at 0°C. for 4 months. These long exposures of tussock moth eggs and larvæ to 0°C. were carried out at approximately saturation (100% relative humidity or 4.6 mm. absolute humidity). At 10°C. and saturation, eggs could be kept for 9 months, and at 80% relative humidity for an equal period of time. In long time exposures relative humidity was hard to control accurately except at saturation. First instar larvæ can be kept at 10°C. at saturation for 3 months; 2nd instar larvæ for 2 months and 3rd instar larvæ for 3 weeks. At saturation humidities, larvæ succumb very easily to fungus infections. The larvæ were not reared under sterile conditions. It may be that they are more adapted to the quantity factor of low temperature than the experiment would indicate.

Larvæ do not resist drying over long periods of time. Eggs however may be kept over $CaCl_2$ for as long as 2 years, and after soaking they have the ability to hatch. With the eggs, not only cold hardiness to the intensity factor, but cold hardiness to the quantity factor also is associated with low humidity, (both relative and absolute).

Thus in the tussock moth we have an insect cold hardy to both the intensity factor and the quantity factor of low temperature. Cold hardiness to the intensity factor is periodic for the organism as a whole, but not for any one stage, and in each stage bears a close relationship to the absolute humidity and to the temperature of the environment.

Since cold hardiness in the tussock moth is correlated with three external environmental factors, all of which are mathematical functions of each other, it was thought that a nonogram would be the best means of showing the interrelation of these three factors (environmental temperature, relative humidity and absolute humidity) to cold hardiness. This method of graphical representation has been used by Henderson (1921) in his studies on the respiratory function of the blood. It is fully explained in Pearl's *Medical Biometry* (1923).

Cold hardiness at a given temperature, relative humidity, or absolute humidity can be read off the nonogram. From experimental data at hand it would seem possible to interpolate cold hardy values, at least between −4.0°C. and −20°C. for tussock moth eggs and 1st instar larvæ, and between −1.5°C.

and −20°C. for the 2nd instar larvæ where temperatures given represent the survival temperature. Extra-polation would not seem justified, since at the extremes of cold hardiness there is more variability than at intermediate temperatures. For example with the present state of knowledge it would be possible to predict the survival temperature of an egg or larva kept at +15°C. or conversely it would be possible to determine at what temperature and humidity an egg or larva would need to be kept in order to survive −12°C., but it would not be possible to predict the temperature and humidity combination necessary to produce an egg or larva capable of withstanding −30°C.

Nonograms have been constructed which show the relationship of environmental temperature, relative humidity, absolute humidity and survival temperature of the egg, 1st instar, and 2nd instar of the tussock moth, (Fig. 3).

Cold Hardiness in the Japanese Beetle.

Japanese beetle larvæ (*Popillia japonica* Newman) are remarkably cold hardy to the quantity factor of low temperature, but only moderately so to the intensity factor. They are, however, able to withstand intense dehydration, but not dehydration over long periods of time. They can survive dessication with a water loss of one-third their body weight, but cannot survive long periods of exposure to drying.

With regard to the intensity factor of low temperature, the three instars behave almost alike, except that the 1st instar is slightly less cold hardy than the 2nd and 3rd. A scale of cold resistance of −7° to −15°C. covers the range of temperature below zero usually survived by the 2nd and 3rd instars, and −7 to −12°C. covers the survival range of the 1st instar larvæ.

A nonogram of the temperature-humidity relationships of the larval instars, and of the adult is shown in Fig. 4. The adult behaves differently with regard to cold hardiness than does the larvæ. It is cold hardy to the intensity factor of low temperature, can survive extreme dehydration, but is not so well adapted to the quantity factor of low temperature as is the larvæ. Although the adult is a summer stage in the life history of *P. japonica* it is as cold hardy as larvæ of oak borers found in Minnesota during the winter. The cold hardy range of the

Japanese beetle adults found in and near Philadelphia is from −20°C. to −40°C. No studies of blood conductivity or freezing point could be made on them because enough blood or

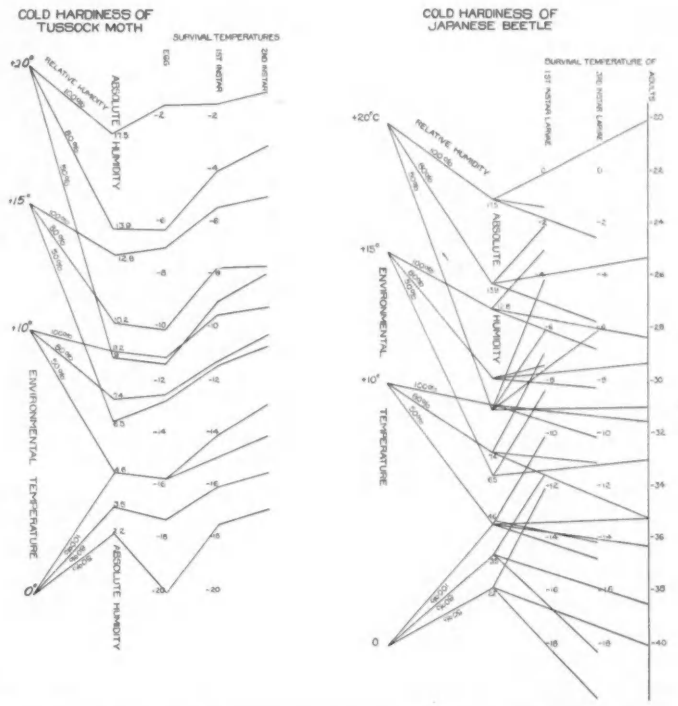

Fig. 3. Cold hardiness in tussock moth eggs and larvæ. The first ordinate from the left records environmental temperature, the second ordinate absolute humidity, the third, fourth, and fifth ordinates represent survival temperatures of egg, first instar and second instar larvæ respectively. The sloping line connecting environmental temperature to absolute humidity is relative humidity. In reading chart, trace the survival temperature of any given stage, back to its corresponding humidity and environmental temperature.

Fig. 4. Cold hardiness of Japanese beetle. Environmental temperature is the first ordinate, absolute humidity the second, and the third, fourth, and fifth, ordinates are survival temperatures of the first instar larvæ, third instar larvæ, and adults, respectively. The sloping line connecting environmental temperature and absolute humidity is relative humidity. In reading chart, trace back the survival temperature of any stage to its corresponding humidity and environmental temperature.

body fluid for a test could not be obtained, even upon extensive dissection. Since previous studies have shown that low moisture content is in general associated with cold hardiness to the intensity factor of low temperature, it may be that the beetle is so constituted that it must be cold hardy. However the cold hardiness of this beetle can be increased still further by exposure to lower temperatures and low humidities, (both relative and absolute). In the nonogram, Fig. 4, cold hardiness is shown for environmental temperatures of 0°C., 10°C., 15°C., and 20°C., and for relative humidities of 50% to 100%, with their corresponding absolute humidities. Exposure to a given temperature was for 5 days in all of the experiments charted on the

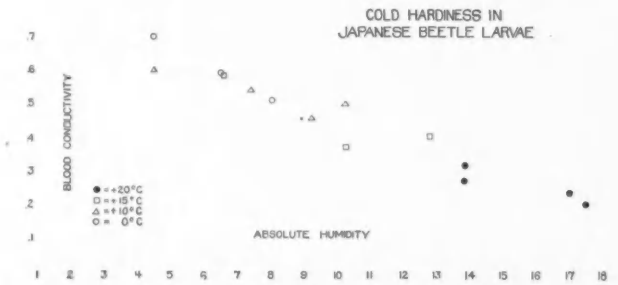

Fig. 5. Cold hardiness in Japanese beetle larvæ as measured by blood conductivity. Blood conductivity is plotted against absolute humidity. Each reading represents a given environmental temperature. Each temperature was used with several humidities.

nonogram, Fig. 4. There appears thus far to be no periodicity in cold hardiness in the adult of the Japanese beetle.

From the larvæ enough body fluid could easily be obtained to make readings of conductivity, pH, or freezing point. In a previous paper, Payne (1927), blood conductivity was used as a measure of cold hardiness in the Japanese beetle 3rd instar larvæ. The figures obtained, plotted against the absolute humidity of the environment in which the larvæ were kept is shown in Fig. 5. There is a tendency for the conductivity to be correlated with absolute humidity, but the correlation is not a linear one as was found for tussock moth eggs and larvæ. Conductivity is not a perfect measure of cold hardiness, and therefore it might be expected that even if the survival tem-

perature and absolute humidity were correlated, the blood conductivity and absolute humidity would show a lower coefficient of correlation than a more direct measure of cold hardiness.

The nonogram of cold hardiness relationships of the Japanese beetle, (Fig. 4), show that environmental temperature is more

Fig. 6. Cold hardiness in the second instar larvæ of the Japanese beetle. Absolute humidity is plotted against survival temperature. Each reading represents an environmental temperature at which larvæ were kept, at a given absolute humidity. With each environmental temperature several humidities were used.

closely related to cold hardiness than is absolute humidity. For example, at an absolute humidity of 4.6 mm. water vapor, the survival temperature of the 3rd instar at 0°C. was −14.6°C., at 10°C. was −1.4°C.; at absolute humidity of approximately 9 mm., for 3rd instar larvæ kept at +10°C. the survival temperature was −10°C., for those kept at +20°C. the survival temperature was −6°C. The 1st difference citied is not signi-

ficant, as it is less than the standard deviation for the mean; the second is probably significant. The 2nd instar larvæ behaved like the 3rd, (Fig. 6). Neither in mean or minimum survival temperatures was there a significant difference between them. In Fig. 7 survival temperatures of 1st instar larvæ are plotted against absolute humidity. There is a correlation of survival temperature and absolute humidity in both larval instars of the Japanese beetle, but in neither is survival temperature a linear function as in all stages of the tussock moth.

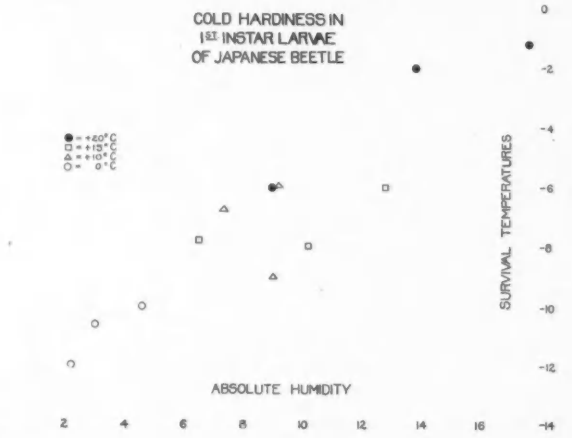

Fig. 7. Cold hardiness in the first instar larvæ of the Japanese beetle. Each reading represents an environmental temperature at which larvæ were kept at a given absolute humidity. With each environmental temperature several humidities were used.

Absolute Humidity as a Factor in Cold Hardiness in the Oak Borer.

Data comparable to that obtained for the Japanese beetle and the tussock moth was not determined for the oak borers, neither in Minnesota nor in Pennsylvania. However the concept of absolute humidity as a factor in cold hardiness clears up certain discrepancies between experimental results and out-of-door observations made in that ecological group. It was shown experimentally that exposure to low temperature increased cold hardiness. Dehydration or exposure to low

relative humidities at room temperature (20°C.–22°C.) also increased cold hardiness. In making climographs of the Minnesota climate near St. Paul, it was found that the highest relative humidity occurred in winter. Larvæ kept out of doors in winter, or collected from moist (at times saturated) environments were still cold hardy, although it was found in general that high humidity was associated with loss of cold hardiness. With the concept of absolute humidity this apparent conflict of experimental results with observations is at once eliminated, for in winter in Minnesota the absolute humidity of the environment of the oak borers *Dendroides canadensis* and *Synchroa*

TABLE VIII.

METEOROLOGICAL DATA, 1927, PHILADELPHIA.

Month	Temperature	Precipitation	Relative Humidity
January	33	1.88	74
February	41	3.66	78
March	54	1.11	79
April	60	3.66	74
May	70	1.75	82
June	78	3.48	73
July	84	4.50	74
August	78	7.27	81
September	78	2.59	73
October	68	5.71	73
November	58	3.59	77
December	46	3.99	70

punctata was low. In experimental hardening likewise the absolute humidity was low. Thus in the oak borer group as well as in the Japanese beetle, *Popillia japonica*, and the tussock moth, *Hemerocampa leucostigma*, low absolute humidity is associated with cold hardiness.

GENERAL DISCUSSION.

In this paper emphasis is laid on one factor in cold hardiness, namely absolute humidity, the relationships and ramifications of which were determined in some detail in two organisms, *Popillia japonica*, Newman, and *Hemerocampa leucostigma* Smith and Abbott. The writer hopes that in bringing this one environmental condition to the front its limitations will not be lost sight of by the reader. Absolute humidity, which is

essentially but one factor in measuring moisture, does not determine the total amount of intensity of low temperature that an animal will survive. Various internal factors such as nutrition, water binding ability (Robinson 1927), health, and above all previous history of the animal upon which experiments performed or determinations are made play important roles in the ability to withstand low temperatures. For example, in the Japanese beetle larvæ a freshly molted larvæ of any of the three instars is not cold hardy. Japanese beetle larvæ with clear digestive tracts are not cold hardy regardless of environment.

TABLE IX

METEOROLOGICAL DATA, 1928, PHILADELPHIA.

Month	Temperature	Precipitation	Relative Humidity
January	35.6	1.91	70%
February	35.1	4.	73%
March	42.	2.10	72%
April	50.6	5.55	70%
May	62.4	2.19	72%
June	69.8	6.77	80%
July	77.4	3.60	77%
August	77.2	5.47	82%
September	65.4	3.61	77%
October	59.9	.73	80%
November	49.	1.94	78%
December	40.8	1.5	70%

Cold hardiness as determined for the species studied at Philadelphia, *Popillia japonica* and *Hemerocampa leucostigma*, will very probably not hold for these same species collected in different climates, or reared at different temperatures. In order that the results found in this paper may be compared with those found in other regions, a climograph for the Philadelphia region, showing relative humidity plotted against temperature, (Fig. 8), and one showing precipitation plotted against temperature, (Fig. 9, Tables VIII and IX), are shown. The tussock moth eggs are exposed to the extremes of low temperature occurring in this region. The Japanese beetle larvæ live in the earth, generally in moist, rarely in sandy soil, and are thus exposed to neither the extremes of humidity or temperature to which tussock moths are exposed.

SUMMARY.

1. Cold hardiness in the eggs and larvæ of the white marked tussock moth, *Hemerocampa leucostigma* Smith and Abbott, bears a linear relationship to absolute humidity.

2. Eggs are slightly more cold hardy than the 1st instar larvæ; the 1st instar larvæ more cold hardy than the 2nd, and the 2nd more than the 3rd.

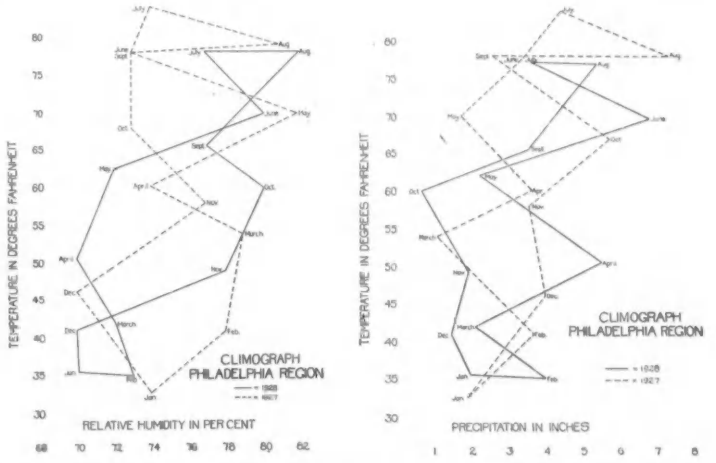

Fig. 8. Climograph of the Philadelphia region. Average monthly temperature in degrees Fahrenheit is plotted against relative humidity as expressed in per cent.

Fig. 9. Climograph (hythergraph) of the Philadelphia region. Average monthly temperature in degrees Fahrenheit is plotted against precipitation expressed in inches.

3. Cold hardy eggs tend to produce cold hardy larvæ.

4. Cold hardiness of the Japanese beetle in relation to absolute humidity, relative humidity and environmental temperature has been determined for all three instars of the Japanese beetle larvæ, *Popillia japonica* Newmann, and for the adults.

Nutrition as a Factor in Insect Cold Hardiness.

Nutrition influenced the cold hardiness of Japanese beetles kept at the same temperature and relative humidity. Diets used for Japanese beetles consisted of vegetable mold from grasslands (not leaf mold), and of vegetable mold plus wheat. The addition of wheat to the leaf mold increased cold hardiness as shown in Tables X and XI.

TABLE X.

Effect of Nutrition on Cold Hardiness of Japanese Beetle Larvæ of Third Instar. (Measured as Survival Temperature). Saturation or 100% Relative Humidity.

	Vegetable Mold	Starved Two Weeks	Starved Four Weeks
Kept at 20°C.....	−2.5± .9	−5.3±1.4	−1.2± .3
Kept at 15°C.....	−6.5±1.4	−8.9±2.0	−4.1±1.6

Starvation of 3rd instar larvæ for two weeks increased their cold hardiness. Starvation for one month decreased it. During starvation larvæ were kept in separate vials in sterile white sand moistened with distilled water.

TABLE XI.

Effect of Diet on Cold Hardiness of Japanese Beetle Larvæ of Third Instar. (Measured as Survival Temperature). 80% Relative Humidity.

	Vegetable Mold	Vegetable Mold Plus Wheat	Starved Two Weeks
Kept at 20°C.....	−3.5± .7	−6.0±1.5	− 7.5±1.9
Kept at 15°C.....	−6.8±1.3	−7.2±2.15	−10.4±2.7

Acknowledgments.

This work was done at the University of Pennsylvania, Department of Zoology, at which place apparatus and facilities for study were made available. To Dr. J. H. Bodine, of the Dept. of Zoology, I owe thanks for helpful suggestions during the course of the work. Dr. Henry Fox, of the Japanese Beetle Laboratory, aided greatly by furnishing the large quantities of

Japanese beetle larvæ used in these experiments. To him I owe thanks for helpful counsel. Finally Dr. H. B. Baker, of the Dept. of Zoology, proposed the concept of absolute humidity as a key to the anomalous behavior of certain organisms with respect to cold hardiness.

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BOOK NOTICE.

REVISION DER PHORIDEN NACH FORSCHUNGSGESCHICHTLICHEN UND NOMENKLATORISCHEN, SYSTEMATISCHEN UND ANATOMISCHEN BIOLOGISCHEN UND FAUNISTISCHEN GESICHTSPUNKTEN, von Dr. Phil. Nat. Hermann Schmitz S. J. of Ignatius-Kolleg, Valkenburg. Published by Ferd. Dummlers Verlag, Berlin SW 68. Quarto, 212 pages, 48 text figs., 2 pls.

This is a beautifully arranged monograph and review of the biological facts known about this family of parasitic flies with keys to genera and a list of the European species with notes on their distribution. It contains considerable original material on the anatomy particularly of the curious glands found in such parasitic insects. The excellence of the volume lies in the painstaking analysis of the material and arrangement of the contents. Any systematist planning a monograph would find this volume full of suggestions as to the arrangement. Some of the twelve parts are: History of the literature and research; Research on types; Natural boundaries of the family; Origin and relationships of the Phoridæ; Anatomy; Classification and keys to genera; Revision of genera; Distribution of European species; Bibliography; Index. The chapter, "Research on types," gives the location and present standing of each author's types and must represent a great amount of labor. It is the type of research that too many systematists avoid. The press work is of the highest standard.

C. H. K.

NATURAL ENEMIES OF THE SUGAR CANE MOTH STALKBORER IN CUBA.[1]

H. K. PLANK,
Central Baraguá, Prov. Camagüey, Cuba.

INTRODUCTION.

The habit which the sugar cane moth stalkborer (*Diatraea saccharalis* Fabricius) has of spending the greater part of its life in tunnels in the stalks of sugar cane, corn, and certain grasses serves as an admirable protection against direct, or artificial, measures of control (9),[2] but does not seem to afford any great amount of protection against the attack of a rather formidable array of natural enemies. Such a condition is indicated in the comprehensive list of sugar cane moth borer parasites recently published by Van Dine (13). In this list, which includes the parasites reported from different parts of the world, there are ten species credited to Cuba. Among these is *Bassus* (*Microdus*) *stigmaterus*, described by Cresson from Cuba in 1865 (2), and reported by Holloway and others (3, 5) as being a parasite of *Diatraea saccharalis*, as well as four other species reported by Cardin in 1915 (1). Since 1915 the remaining five species have been reported by various authors.

In the investigations conducted by the Cuba Sugar Club Experiment Station since 1925, all but two of the ten parasites listed have been encountered. Observations and records on these and a number of other parasites, as well as predators, have been made under various conditions. It is the purpose of this paper to present these observations, together with a summary of all the information available up to the present time, to serve as a guide should efforts be made to introduce and colonize new species. The species are treated in the order of their abundance and placed in groups according to their major or minor importance.

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[1]Scientific Contributions No. 15, Tropical Plant Research Foundation. From the Cuba Sugar Club Experiment Station, Baraguá, Province of Camagüey, Cuba.

[2]Figures in parentheses refer to the "List of References" at the end of this report.

Major Parasites.

The species considered under this heading have been encountered most frequently in Cuba. Collectively they have been observed to parasitize about half of the borers in some localities during certain seasons of the year.

Lixophaga diatraeæ Townsend.[3]

Lixophaga diatraeæ Tns. (Figs. 1 and 2)[4], commonly referred to as "The Tachinid," or "Cuban Fly," has been found in more localities in the Island of Cuba than any other parasite.

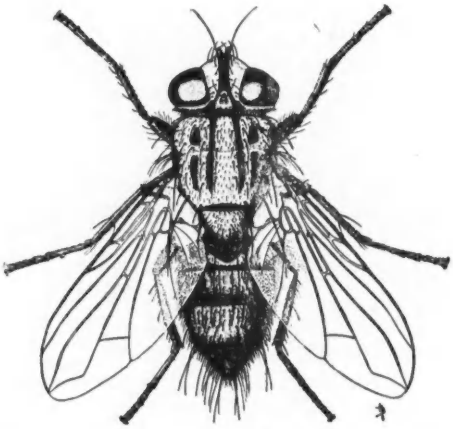

Fig. 1. *Lixophaga diatraeæ* Townsend, "Tachinid," or "Cuban fly," parasite of the sugar cane moth stalkborer, greatly enlarged. (Holloway, Haley, and Loftin).

Wolcott (16) found it in various places in the provinces of Habana, Santa Clara, Matanzas, and Oriente in 1914, and estimated that "25 per cent of the borer larvæ in Cuba that are half grown or larger will be found to be parasitized by the Tachinid fly maggot." Holloway and Loftin (3, 4), who collected and sent more than 650 of the puparia of this fly to Louisiana, estimated that "from 20 to 50 per cent of the moth

[3]Order Diptera, family Tachinidæ.

[4]The photographs for all except Figures 1 and 6 were made by Mr. L. C. Scaramuzza.

borer larvæ were parasitized" at Central Mercedes, Matanzas Province, in the summer of 1918. Van Zwaluwenburg (14, 15) collected puparia of this parasite for shipment to Mexico during the summer of 1922 and found it very abundant in the provinces of Habana and Matanzas. Salt (10) found *Lixophaga* present in about 3.5% of the infested canes at Central Soledad, Santa Clara Province, in 1926. In the field survey made by this Station during the crop of 1927-28, in which were included

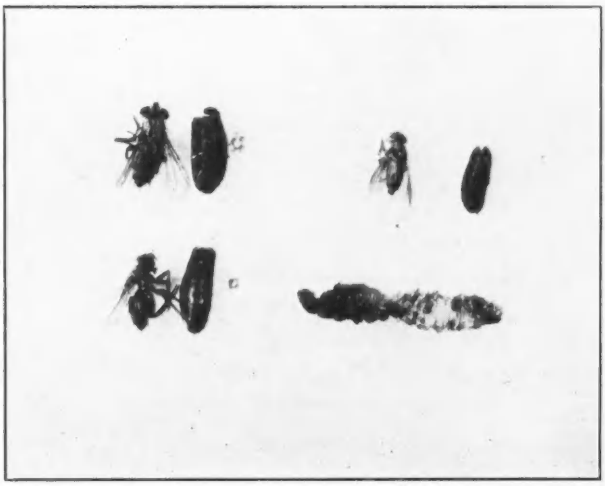

FIG. 2. *Lixophaga diatraeæ* Townsend, "Tachinid," or "Cuban fly," parasite of the sugar cane moth stalkborer, mounted to show various views of the adult and range in size of the adults and of the puparia (shown at right of each). Remains of a borer killed by the maggot shown at lower right. Enlarged twice.

eight centrals in the provinces of Matanzas, Camaguey, and Oriente, puparia of this fly were found at all but one central. The average percentage of parasitized borers at the time the collections were made at these seven mills was 9.7%, of which 8.8% were *Lixophaga*. A survey of 32 centrals, including the above, in six provinces, made from December, 1928, to May, 1929, showed that this parasite was present at all but two centrals. (See Table I). It is very probable that if more extended observations could be made at these two centrals,

Lixophaga would be found there also. It is thus seen that this species has been found in all of the provinces and that it is well distributed over the entire Island.

TABLE I.

DISTRIBUTION OF THE MAJOR PARASITES OF THE SUGAR CANE MOTHS STALKBORER, CUBA, 1926–1929, INCLUSIVE.

PROVINCES AND CENTRALS VISITED	SPECIES FOUND, OR REARED			
	Lixophaga	*Apanteles*	*Bassus*	*Trichogramma*
Pinar del Rio				
San Cristobal	X	X	X	
Orozco	X			
Marcedita	X			
Total, 3	3	1	1	
Habana				
Hershey	X			
Gomez Mena	X			
Total, 2	2			
Matanzas				
Conchita	X	X		
Cuba	X	X	X	X
Mercedes	X			
Total, 3	3	2	1	1
Santa Clara				
Soledad (Cienfuegos)	X			
Trinidad	X			
Adela	X			
Total, 3	3			
Camaguey				
Jathibonico	X			
Punta Alegre	X			
Moron	X			
Jagueyal	X			X
Baragua	X	X		
Jaronu	X	X	X	X
Florida	X			
Agramonte	X			
Vertientes	X			
Santa Marta	X		X	
Total, 10	10	2	2	2
Oriente				
Jobabo	X		X	
Rio Cauto	X		X	X
Cupey	X			
Maceo				
Baguanos				
Tacajo	X			
Preston	X			X
Miranda	X			
Ermita	X		X	
Cape Cruz	X			X
Isabel (Media Luna)	X			
Total, 11	9		3	3
Grand Total, 32	30	5	7	6

Table II shows the results of the examinations made on the seasonal occurrence of the natural enemies of the borer at Central Jaronù during the three years 1926 to 1928. This

TABLE II.

OCCURRENCE OF THE NATURAL ENEMIES OF THE SUGAR CANE MOTH STALKBORER, CENTRAL JARONU, CAMAGUEY PROVINCE, CUBA, 1926–1928, INCLUSIVE.

SPECIES	Living parasites found, or reared, from borer eggs ("e"), larvæ ("l"), and pupæ ("p").											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Parasites: *Lixophaga diatraea* Tns.	1 p	1	1	1, p	1	1, p	1, p	1	1	1	1	1, and on wing
Apanteles diatraea Mues.	1	1	.....	.....	.....	1	1	1	1	1	1	1
Bassus stigmaterus (Cress.)	1	.....	1	.....	1	1	1, p	.....	.....	.....	1	.....
Trichogramma minuta R.	.....	.....	e	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sarcophaga sternodontis Tns.	p	p	.....	.....	p	1, p	p	p	p	p	.....	.....
Sarcophaga helicis Tns.	.....	.....	.....	.....	.....	.....	1	.....	1	.....	.....	.....
Sarcophaga surrubea VDW.	.....	.....	.....	.....	.....	1, p	.....	.....	.....	1	.....	.....
Sarcophaga pedata Ald.	.....	.....	.....	.....	.....	.....	p	.....	.....	.....	.....	.....
Chaetopsis fluvifrons Macq.	.....	.....	.....	.....	p	.....	.....	.....	.....	.....	.....	.....
Predators: *Prolabia unidentata* Palis.	.....	1	.....	.....	.....	.....	p	1	.....	1	1	.....
Doru lineare Esch.	p	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Anisolabis sp.	p	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Anisolabis annulipes Luc.	.....	.....	.....	.....	.....	.....	.....	p	p	.....	.....	.....
Pyrophorus spp.	.....	.....	.....	.....	.....	.....	p	.....	.....	.....	p	.....
Lecon. sp.	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
Monomorium floricola Jerd.	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
Solenopsis corticalis var.	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....
Prenolepis sp.	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....
Undetermined ants	.....	.....	.....	.....	.....	p	1	.....	p	.....	.....	.....

central is located on the north coast of the province of Camaguey. It will be noted that living specimens of *Lixophaga* have been seen, or have been reared from borer larvæ, in every month of the year. In addition, from collections of borers made in January, April, June, and July *Lixophaga* was reared from the borer pupa, and in December specimens of the adult, or fly, were seen flying about in the cane fields.

Observations made at frequent intervals, in certain fixed areas, and extending over long periods have shown that the

percentage of parasitism by *Lixophaga* is quite variable throughout the year and from year to year. In one locality in 1926 it varied from 10% in July to about 40% in September (8). In another similar locality during 1927 an average of 7.6% was noted for the period from April to the following February. In this case the maximum efficiency of the parasite was exhibited during April and the minimum during July.

The method by which this parasite deposits its eggs has not been discovered. Numerous attempts have been made to induce oviposition in various types of laboratory cages, but all have been unsuccessful. No observations have been made in the field which would give an indication of the egg-laying habits.

Lixophaga diatraea is a parasite of the larva of *Diatraea* that occasionally delays its emergence until after the borer has pupated. Holloway (3) and the writer have reared it a number of times from borer pupæ, but these instances were rare when compared with the frequency with which it was recovered from the larva. Rarely has it been reared from borer larvæ less than one-third to one-half grown when collected, and the borers were nearly always full grown by the time the parasite larvæ, or maggots, emerged from them. Usually only one parasite maggot has issued from a borer larva or pupa, but occasionally two and less frequently three have been seen to emerge.

When full-grown the larva of *Lixophaga* occupies nearly all of the interior of the host and its movements therein make the latter appear to be alive up to the time when emergence takes place. After emergence the maggot seeks a dry place in which to change to the pupal stage. (See Fig. 3). This change usually takes place within a few hours, but has been observed to require a much longer time. Wolcott (16) found 2 days the maximum time required during the winter of 1914.

When the puparium, or transition stage from larva to fly, is first formed it is light yellow in color, but changes within a few hours to amber color and finally to black by the time the fly is ready to emerge. It is always slightly curved with the ends well rounded as shown in Figs. 2 and 3. In the young cane shoots it is usually formed at or near the opening of the borer tunnel, often some distance above the remains of the borer larva, which thus insures its exit from the cane stalks.

Sometimes it will be found between the loose dry outer leaves, especially if the shoot be large and almost dry. In stalks that have developed joints, the puparium will be found in or near the mouth of the larger borer tunnels and within about two inches from the outside (Fig. 3, "P"). Nearly always this part of the exit tunnel has been found open and free from the usual silk and other material which the borer places there before it pupates. The fly is thus able to find its way to the outside when it emerges from its puparium.

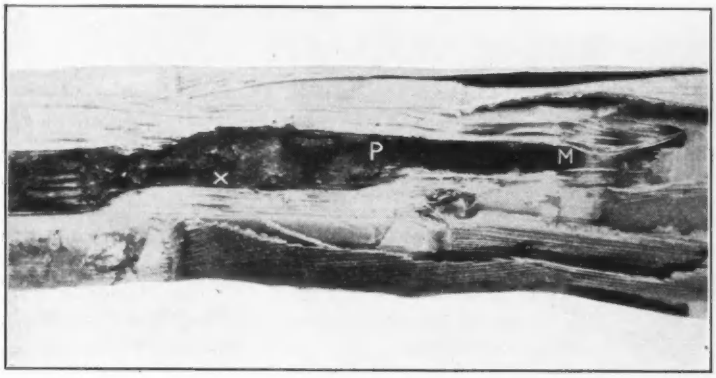

FIG. 3. Piece of cane stalk opened to show relative position of puparium, "P," of *Lixophaga diatraeæ* Tns. near mouth, "M," of tunnel made by the sugar cane moth stalkborer. Remains of borer larva shown at left of "X." Enlarged twice.

Inasmuch as it is not known when egg-laying takes place, the length of time required for the larval stage cannot be given. Sometimes as many as 25 days elapse after the borer larva has been collected in the field before the parasite larva emerges. The average time noted between collection and emergence of the parasite was about 8 days.

The length of time in the pupal stage has been observed to vary from 7 to 11 days, about 10 days being the average under conditions normally found in Cuba during May, June, and July. In cool weather, or in artificially cooled containers, this period may be prolonged to double the time without apparent injury to the emerging fly. This is of great importance in considering the shipment of the fly from one country to another.

After normal emergence, the adults may live as long as three days without food. With sugar syrup, or other suitable material, their life may be prolonged, but, even when thus fed in a protected screen cage in an outdoor rearing shelter, all were dead within a period of 10 days. No observations have been made on the mating habits.

Very few natural enemies of *Lixophaga* have been found in Cuba. While making some examinations in young cane at Central Jaronù, W. E. Haley of the U. S. Bureau of Entomology found four *Lixophaga* puparia that had been eaten into presumably by a species of earwig. The writer found some small maggots feeding on a *Lixophaga* larva that had just issued from a borer in its tunnel. The flies reared from these maggots were subsequently determined as *Aphiochaeta* sp. by C. T. Greene of the U. S. National Museum. In 1919 Holloway (3) wrote that *Lixophaga* has to contend with a secondary parasite in Cuba, but did not state what it was. No secondary parasites have been encountered in the present work.

From the data gathered thus far in districts which are located on the north coast of the province of Camaguey, it appears that rainfall and the predominance and availability of certain stages of the larvæ of *Diatraea* are the most important limiting factors in the efficiency and development of *Lixophaga*.

The highest percentage of parasitized borers was generally found to coincide with or follow periods of rainfall. In 1926, a year of excessive rainfall, except in March and May, there was an increase in the percentage of parasitized borers found, from 10% in July to 40% in September. During 1927, a year of light rainfall, except in March, August, and September, the percentage of parasitized borers showed a decided decrease as the season advanced and during June, July, and August practically none could be found. After August 15 the borer population gradually increased with the age of the cane, and parasitism then seemed to follow more closely the periods of greatest abundance of the one-third- to one-half-grown borers, but never became greater than 17.5%.

That the majority of flies are on the wing and that parasitism takes place generally during these periods is clearly indicated by the fact that the largest numbers of empty *Lixophaga* puparia are found during or just before these periods. Since at almost any time of the year more puparia are found in the

dead hearts than in the stalks, it appears that the size of the infested stalk, and hence the availability of the borer for parasitism, also has some influence on the seasonal abundance of *Lixophaga*.

The most important artificial condition that limits the abundance and effectiveness of *Lixophaga* is the burning of the cane trash, either before or after harvest. This conclusion is based on observations made in 1926 (8) and 1927 of both burned and unburned fields. The two fields under observation in 1926 were again examined on April 12, 1927, 11 weeks after the previous crop had been harvested and about 10 weeks after the trash in the burned field had been burned off. The examination in the burned field yielded no parasites, while 19.2% of the borers collected in the adjacent unburned field harvested at the same time were found to be parasitized by *Lixophaga*. Unfortunately an accidental fire swept over the unburned field and made further examinations along this line impossible. Observations made in burned-over fields elsewhere, however, showed that parasitism was not effective until late in the season, at which time the borer infestation was much greater and the parasitism much less than in the nearby unburned fields of the same age.

Another artificial condition that limits the abundance of this Tachinid parasite is the removal of dead hearts as a plantation measure in borer control. This was indicated in the dead heart cutting experiment conducted in 1926 (7). In the examinations made in January, about 6 months after the latter of the two cuttings was completed, it was discovered that there were approximately one-half as many borers parasitized by *Lixophaga* as in the adjacent check fields. In this case the dead hearts were removed and destroyed without any effort being made to allow the parasites to emerge and return to the fields.

Mention should be made here that, through cooperative arrangements between the U. S. Bureau of Entomology and the Florida Agricultural Experiment Stations, 1760 larvæ and puparia of *Lixophaga* were sent to the United States for colonization at Bradenton and Lake Alfred, Florida, during 1926 and 1927.

Apanteles diatraeæ Muesebeck.[4]

This parasite was first reported in Cuba by Cardin in 1915 (1) as *Microgaster* sp., and during the early part of the present investigation Van Dine (12) and the writer (8) used the name *Microgaster* sp. to designate this parasite. Recently, however, Cardin's material was made available by Mr. S. C. Bruner of the Estacion Experimental Agronomica at Santiago de las Vegas. This material and specimens reared by the writer were

FIG. 4. *Apanteles diatraeæ* Muesebeck, parasite of the sugar cane moth stalk-borer, enlarged twice. Remains of a borer killed by the grubs at left, groups of cocoons taken from borer tunnels in center, and adult parasites at right.

referred to A. B. Gahan of the U. S. National Museum for determination. Mr. Gahan identified all specimens as *Apanteles diatraea* Mues. As a result of this determination, the mention of *Microgaster* sp. in Van Dine's list (13), on the authority of Cardin, refers to the species under discussion.

Apanteles diatraeæ (Fig. 4, right), is a small parsite of the borer larva and has ranked next to *Lixophaga diatraeæ* Tns. both in abundance and importance. Holloway (3) states that U. C. Loftin he and found what was subsequently determined as *Apanteles* sp. "comparatively rare" at Mercedes, Matanzas

[4]Order Hymenoptera, family Braconidæ.

Province, during 1915 and 1918. The specimens collected by Mr. Holloway at this place in September, 1918, were described by Muesebeck in 1920 (6) as *Apanteles diatraeæ* n. sp. Van Zwaluwenburg (15) reared the same species from material collected in *Diatraea* tunnels in sugar cane in the province of Matanzas, Cuba, where he said it appeared to be uncommon. The writer has found this parasite at five other centrals in the provinces of Pinar del Rio, Matanzas, and Camaguey. (See Table I). While this parasite is now known to occur in Cuba in only these three provinces, it is probably present in other parts of the Island as well.

In the northern part of Camaguey Province where the following observations were made, living specimens of this parasite were found in all months of the year except March, April, and May. (See Table II). The period of greatest activity was confined to the late summer, fall, and winter months. During these periods as high as 4% of the borers collected were parasitized by this species but the average is much less.

All attempts to induce egg-laying in cages were unsuccessful. Several types of cages were used and borers varying from about half-grown to full-grown were exposed to the adult parasites, but there was no indication of oviposition, and no parasites were reared.

The *Apanteles* larva, or grub, is about 3 mm. to 4 mm. in length. The number that may develop in a borer larva varies, a maximum of 40 having been observed. Once free from the host, which they leave in a shriveled condition (Fig. 4, left), the larvæ congregate in a group and move about in search of a place in which to spin their small, white cocoons. The usual place selected is in the upper part of the borer tunnel at a point near its mouth. The cocoons are stuck together in a group, or mass, which conforms to the surface on which it is formed. The groups found in the tunnels are nearly cylindrical in shape and, depending on the number of cocoons, are about one inch long. (See Fig. 4, center).

The length of time required for the larval stage is not known, but a maximum period of 47 days between the time of collection and emergence of the parasite larvæ has been noted during the winter months. The length of time in the pupal, or cocoon, stage has varied from 10 to 12 days, 11 days being

the average time observed during October and February. Adult life in confinement is comparatively short, but some adults have been observed to live about two weeks under laboratory conditions.

As no secondary parasites or other natural enemies have yet been observed to attack *Apanteles*, it is believed that other natural conditions are accountable for its comparatively limited activity in Cuba. Omitting consideration of the possible food plants of the adults, which have not been investigated, climatic

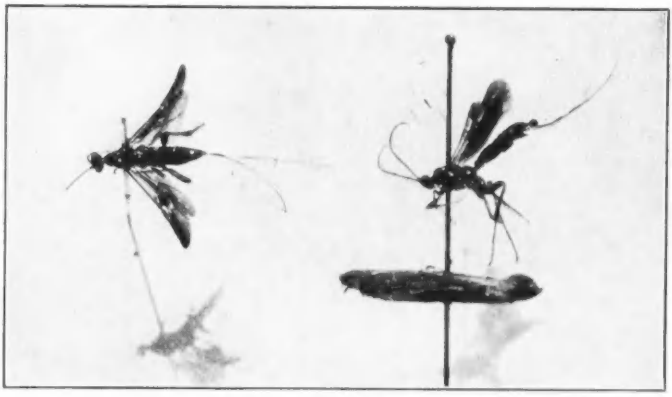

FIG. 5. *Bassus stigmaterus* (Cresson), parasite of the larva of the sugar cane moth stalkborer, enlarged twice. (a) Top view of female, (b) Side view of female and cocoon.

conditions seem to be the most important factors involved. That the greatest parasitism by this species has usually been found during the fall and winter months, which in Cuba are cool and dry, indicates that relatively low temperatures affect *Apanteles* activity more favorably than does rainfall.

The burning of the cane trash delays considerably the appearance of *Apanteles*. In a field burned in February, none of these parasites were found until the cane was about 11 months old, the following January. In an adjacent unburned field, *Apanteles* was recovered 6 months earlier than in the burned field.

During the summer and fall of 1927, 161 groups of cocoons containing living *Apanteles* were sent for colonization purposes

to Mr. T. E. Holloway, in charge of the Sugar Cane Insect Laboratory of the U. S. Bureau of Entomology at New Orleans, La.

Bassus stigmaterus (Cresson).[5]

This parasite has previously been referred to as *Bassus stigmaterus* Cresson (8, 11, 12, 13). However, specimens from the area under observation since been submitted were identified to the U. S. National Museum, by Dr. R. A. Cushman as *Bassus diatraeæ* Turner, and this name was used in a subsequent publication (9) to designate this species.[6]

Bassus stigmaterus Cresson (See Fig. 5), has been found principally at one central in the province of Camaguey. In the parasite survey just completed, cocoons were found at one more central in this province and at four centrals in the provinces of Matanzas and Oriente; in addition a living larva was found at one central in the province of Pinar del Rio. (See Table I). Including Holloway's collection record (3, 5) at Central Mercedes, Matanzas Province, reported as *Bassus stigmaterus* Cresson, the known occurrence of this parasite now covers eight centrals in four different provinces. At one central in Camaguey Province living specimens have been found or reared during the months of January, March, May, June, July, and November. (See Table II). It is still considered rare, however, despite the fact that it occurred in some abundance and was quite active at this central during the summer months of 1926 (8). At that time some living pupæ of this parasite were

[5]Order Hymenoptera, family Braconidæ.

[6]The Synonymy of *Bassus stigmaterus* (Cresson), by R. A. Cushman, Bureau of Entomology, U. S. Department of Agriculture.

Microdus stigmaterus Cresson, Proc. Ent. Soc. Phila., vol. 4, 1865, p. 65 (Cuba).
Microdus diatraeæ Turner, Bul. Ent. Research, vol. 9, pt. 1, 1918, p. 82 (British Guiana).
Microdus crossi Brethes, Revista Ind. and Agric. de Tucuman, vol. 17, 1927, p. 163; Bul. Ent. Res., vol. 18, pt. 2, 1927, p. 205 (Translation into English), (Argentina).

In arriving at this synonymy I have compared five specimens from Cuba with the description of *stigmaterus*, eighteen specimens from British Guiana with that of *diatraeæ*, and two specimens from Argentina with that of *crossi*, and have then compared these specimens with each other. All were reared as parasites of *Diatraeæ*. I find considerable variation in color, especially of the head, the anterior portion of the thorax, and the legs. The sculpture of the basal segments of the abdomen and of the propodeum is also very variable. These variations are not associated with geographical source, the British Guiana specimens displaying practically the entire range in both color and sculpture. Such variations are not unusual in *Bassus*.

sent to Mr. Holloway at the U. S. Sugar Cane Insect Laboratory, New Orleans, La., in an effort made to colonize it there.

Bassus is a larval parasite; but like *Lixophaga*, it sometimes delays its emergence until after the borer has pupated, as the writer has reared it on one occasion from a borer pupa. No observations have been made on egg-laying, either in the laboratory or in the field. The individuals reared thus far have issued from borers that were nearly full-grown, and in 18 days after collection. Not more than one *Bassus* has ever been observed to issue from a single borer larva or pupa. The cocoons (Fig. 5 (b)) were found in about the same locations in the stalks as those of *Apanteles* and the puparium of *Lixophaga*, that is near the exit of the borer tunnel. The length of time in the cocoon stage has been observed to extend over a period of 12 days in November.

All the factors that limit abundance are not known. No secondary parasites have been noted. It is possible that the distribution of food plants of the adult might be of considerable importance. The burning of trash in cane fields appears to be a more serious limiting factor in the case of *Bassus* than of any of the other parasites. During the harvest of 1926-27, the colonia where this parasite was found in abundance in 1926 was swept by a fire which burned all of the trash in most of the harvested fields, as well as a large amount of standing cane. During the following spring and summer no evidence of *Bassus* in this area could be found.

The importance of *Bassus* in borer control is emphasized by the fact that it is active during the summer months when all the other important parasites are less in evidence. This time of the growing season is a critical period in the development of *Diatraea*, inasmuch as it is a period when the cane is growing rapidly and the borer population is almost stationary. As has been shown, *Lixophaga* is active in the spring and *Apanteles* in the fall and winter months. *Bassus* thus seems to supply a chronological sequence in the parasitism of the borer.

Trichogramma minuta Riley.[7]

Although reported by Wolcott (16) and mentioned by Holloway (3) as having been found at Mercedes, Matanzas Province, in 1915 and 1918, this minute parasite (Fig. 6) of the eggs of *Diatraea* and other moths was not encountered in

[7]Order Hymenoptera, family Trichogrammidæ.

the present investigations until recently. During the months of March to July, 1928, and January to May, 1929, collections of borer egg masses from the leaves of young cane were made at 16 centrals widely separated in the provinces of Habana, Matanzas, Santa Clara, Camaguey, and Oriente to determine the range of this parasite. It was found to be present at only 6 centrals, located in the provinces of Matanzas, Camaguey, and Oriente. (See Table I). The egg masses of the borer that yielded parasites constituted from 9% to 100% of the total number collected at these centrals, 31.7% being the average. One mass had only one egg parasitized.

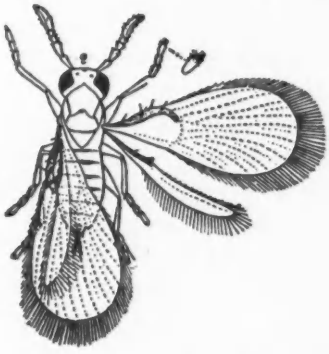

FIG. 6. *Trichogramma minuta* Riley, parasite of the eggs of the sugar cane moth stalkborer, highly magnified. (Riley).

Collections made in March and April, when the cane was about 2 to 4 months old, showed a higher percentage of egg masses parasitized by *Trichogramma* than those made later. None of the eggs collected in July showed any parasitism and no evidence of *Trichogramma* activity has been noted in the fields during the remainder of the season. This apparent inability to prolong early-season activity, and thus to affect the decided increase in borer infestation generally noted during the fall and winter, may be caused by a number of factors, such as the number of *Diatraea* eggs available, their distribution and accessibility, and the presence of alternate *Trichogramma* hosts in the vicinity of the fields. It is evident that the efficiency of *Trichogramma* would also depend largely on whether it parasitized all the eggs in the mass. Although as many as 14 small borers have been found in a single shoot of

young cane, usually only one survived to reach maturity. This one borer is all that is necessary to cause the death or serious injury of the stalk. In older cane, rarely have more than 2 or 3 borers been found in the same stalk, unless it was quite old or very long. Hence, if all the eggs in the mass are not parasitized, the cane stalk will become infested and the larva or larvæ therein reach maturity and damage the stalk. *Trichogramma* will then be killing only those borers which would never have reached maturity under ordinary conditions.

Minor Parasites.

In this group are included insects that have been reared from the larvæ and pupæ of *Diatraea saccharalis* and that are of doubtful or little importance in the natural control of the borer.

Sarcophaga sternodontis Townsend.[8]

Sarcophaga sternodontis (Fig. 7) is the most important of the minor parasites of *Diatraea* in Cuba. Van Zwaluwenburg (14, 15) seems to have been the first to record it from Cuba, having reared it from borer pupæ collected in the provinces of Habana and Matanzas during the summer of 1922. The writer has observed it at three centrals located in the provinces of Habana, Camaguey, and Oriente, and it is probably as well distributed as *Lixophaga*. This species of *Sarcophaga* has usually been reared from the borer pupa, but occasionally it has been reared from larvæ that had been injured while being collected in the field. It has been encountered in the field in all months of the year except March, April, November, and December. (See Table II). It is apparently as abundant at one season as another, but the percentage of borers parasitized by it has always been very low. During 1926 and 1927, 90 puparia were collected and sent to Canal Point and Lake Alfred, Florida, for colonization.

The puparium of *Sternodontis* is usually found in the same location as that of *Lixophaga*, from which it can be readily distinguished by the fact that it is larger, not curved, and has two short spines on one end. (See Fig. 7, left, and compare with Fig. 2). The maximum time elapsing between collection and emergence of the maggot was 12 days. The length of time in the pupal stage was about 8 days.

[8]Order Diptera, family Sarcophagidæ.

Sarcophaga helicis Townsend.[8]

The species was reared from larvæ of *Diatraea* by the writer on July 24, 1926, and in September, 1927, at Central Jaronù, Camaguey Province. (See Table II). Specimens from these rearings were determined by Dr. J. M. Aldrich of the U. S. National Museum, who stated that "this insect is sometimes parasitic, but more often a scavenger feeding on dead insects." It has never appeared to be very abundant,

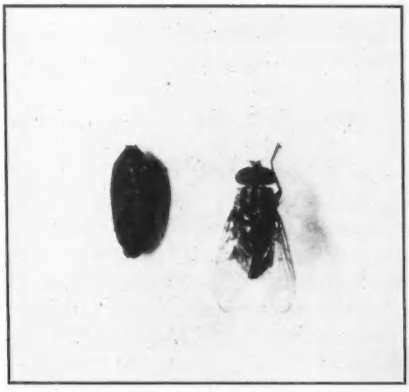

FIG. 7. *Sarcophaga sternodontis* Townsend, parasite of the pupa of the sugar cane moth stalkborer, enlarged twice. Puparium at left.

although it will probably be found in other parts of the Island. The puparia are much smaller than those of *sternodontis*, being about the size of small *Lixophaga* puparia, but are not curved. Sufficient puparia were recovered during the summer of 1927 to send 65 to United States, 12 going to Mr. Holloway at the U. S. Sugar Cane Insect Laboratory at New Orleans and 53 to the Citrus Substation of the Florida Agricultural Experiment Stations at Lake Alfred.

Sarcophaga surrubea VDW.[8]

During the summer and fall of 1927 this species was reared from *Diatraea* larvæ and pupæ that were collected in dead hearts on two colonias at Central Jaronù. (See Table II). It was reared more frequently, however, from borer larvæ

[8]Order Diptera, family Sarcophagidæ.

that had been cut or otherwise injured in collection. Specimens submitted to the U. S. National Museum were determined by Dr. Aldrich as this species. The maximum period of time between collection and emergence was 12 days. The length of time in the pupal stage varied from 4 to 16 days.

Sarcophaga pedata Aldrich.[8]

A small number of adults of this species, determined by Dr. Aldrich, emerged in a cage containing both injured and uninjured borer pupæ collected in dead hearts on July 28, 1927. The larvæ issued from the host material on August 9 and 11 and pupated the same day, the adults emerging August 22. This is the only record of the recovery of this species from *Diatraea* in the present work.

Chaetopsis fluvifrons Macq.[9]

The maggot of this species commonly infests the decaying center of cane shoots that have been killed by borers. A maggot was found issuing from a pupa of *Diatraea* collected in a tunnel in a cane stalk by T. S. Ross on May 24, 1927. This maggot subsequently developed into an adult of *Chaetopsis*. The determination was made by Dr. C. T. Greene of the U. S. National Museum. It is not known when or how this maggot entered the borer pupa.

PREDATORY INSECTS.

Only occasionally have any insects been observed to prey on the larva or the pupa of *Diatraea saccharalis* in Cuba. The following species are the only ones that have been found thus far in this work. Altogether they have never been noted to be any considerable factor in borer control.

Prolabia unidentata Palis.[10]
Doru lineare Esch.[10]
Anisolabis annulipes Luc.[10]
Anisolabis sp.[10]

These earwigs have been found more frequently in *Diatraea* tunnels than any other predators thus far noted. While found principally at Centrals Jaronù and Baraguá in the province of

[8]Order Diptera, family Sarcophagidæ.
[9]Order Diptera, family Ortalidæ.
[10]Order Dermaptera, family Forficulidæ.

Camaguey, they undoubtedly occur commonly in cane fields throughout Cuba. The above species have been determined by A. N. Caudell of the U. S. National Museum.

Prolabia has been observed preying on both the larva and the pupa of the borer, and the other three species on the pupa only, at various periods of the year. (See Table II). Although earwigs have been found in infested cane shoots less than one month old, they were more commonly encountered in cane of 6 months or older. It appears that at this time they can more readily gain entrance to the borer tunnels. In older cane as many as 12.6% of the stalks have been found in a single examination to contain earwigs in the borer tunnels. Usually, however, only about one or two will be found in a hundred stalks. From October to the following February was the period when the largest numbers were found on one colonia during 1927-1928, January being the month of greatest abundance.

Pyrophorus spp.[11]

Larvæ of at least two distinct species of *Pyrophorus* have been encountered frequently in *Diatraea* tunnels throughout the year. In only a few instances, however, have they been observed to prey on the borer, and in these it was only the pupa that was attacked. (See Table II). The larvæ were about 1 to 1½ inches long, rather stout, and of yellowish color when found. They were sent to the U. S. National Museum and determined by Dr. A. G. Boving.

Lecon sp.[11]

The larva of another wireworm was found in a small dead cane shoot on May 5, 1927, when the cane was about 2 months old. At first it was thought that it had killed the shoot, which appeared like the ordinary dead heart caused by *Diatraea;* but when submitted for determination, Dr. Boving assigned it to this genus with the note that "this larva is predaceous, feeding on other insects and their larvæ or pupæ."

Monomorium floricola Jerd.[12]
Solenopsis corticalis var. **vigula** Forel.[12]
Prenolepis sp.[12]

These three species of small ants, the first and last predominantly dark brown and the second light amber in color,

[11]Order Coleoptera, family Elateridæ.
[12]Order Hymenoptera, family Formicidæ.

have been noted at various times and places throughout the spring and early fall inhabiting the tunnels made by the borer and feeding on the borer larvæ therein. (See Table II). Twelve other species have been encountered in similar locations, but, except in the case of 3 undetermined species one preying on the larva and two preying on the pupa, complete evidence on their predatory habits was lacking. They all occupy tunnels made in cane of all ages, but tunnels made in dead hearts and very old cane seem to be preferred. The determinations were made by Dr. W. M. Mann, formerly of the U. S. National Museum.

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SOIL ANIMALS INJURIOUS TO SUGARCANE ROOTS.

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For many years the Louisiana Planters have been concerned over a complex of troubles affecting sugarcane roots. In certain fields the plants are stunted, particularly during the second year (stubble cane), can be pulled out of the ground easily, and upon examination the roots appear abnormally reduced in number and size, and are pitted and rotted to an extent that proper nourishment of the parts above ground is impossible. Scientific workers have attributed this "Growth Failure" or "Root Rot" to several distinct causes; Carpenter (1919, 1921), Matz (1920), Earle (1920), Edgerton and Moreland (1920), and Bourne (1922), working in different localities, thought the injury due to fungi of one kind or another. On the other hand Rands (1924) indicted a species of snail (*Zonitoides arboreus* Say) as an important factor, indicating that these molluscs eat pits in the roots and furnish points of initial attack for root rotting fungi.

In July, 1926, the Entomologists of the Louisiana Experiment Station were authorized to investigate further the part played in this Root Rot complex by snails, with the idea of eventually finding means of control for the molluscs, if important, and thereby eliminate the "pitting" and transmission of the fungous rots by the snails. Cooperation was arranged with the Plant Pathologists of the Louisiana Station who were investigating the fungi.

Recent publications by Edgerton and Tims (1927) and Tims and Mills (1927) indicate that species of *Pythium* are responsible for some of the root rot, that there is no correlation between abundance of "pitting" and abundance of snails, and that most of the "pits" do not enter the active stele of the root, but only affect the outer cortex. Also, Muir (1926) and Van Zwaluwenburg (1926, 1927) in Hawaii report "pitting" from *Collembola* (*Isotomodes* sp.) and certain centipedes, and root injury from nematodes. Matz (1920) also reports pitting by species of this last group.

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Preliminary Survey.

In taking up this study, it was deemed necessary to make a general survey of affected fields in the different parishes of the Sugarcane Belt of Louisiana. In each locality sugarcane stubbles were dug and with the surrounding soil were examined for snails and other animals, as well as root injury. "Pitting" of the roots was found everywhere and a distinct Cane Root Fauna was brought to light. Table I lists the more abundant of the species found.

TABLE I.

Soil Animals of Sugarcane Fields.

Class and Order	Species	Numbers	Stages
Mollusca	*Zonitoides arboreus* Say	Many	All
Annelida	*Lumbricus* sp.?	Few	Adult
	Lumbricus sp.?	Many	Immature
Diplopoda	1 species undetermined	Few	Adult
Chilopoda	2 species undetermined	Few	Adult
Symphyla	*Symphylella* sp	Many	All
Arachnida	3 species of mites	Many	All
Insecta, (Collembola)	*Lepidocyrtus violentus* Fols	Many	All
	Orchesella ainsliei Fols	Many	All
	Neanura muscorum Fols	Few	All
	Proisotoma minuta Tull	Many	All
	Onychiurus armatus Tull	Many	All
(Coleoptera)	*Elateridæ*, species of	Several	Larvæ Adults
	Scarabaeidæ, species of	Several	Larvæ Adults
	Ptilodactyla serricollis Say	Several	Larvæ
	Chauliognathus marginatus Fab.	Few	Larvæ
	Rhyncophora, species of	Few	Adults
	Staphylinidæ, species of	Many	Adults
	Carabidæ, species of	Several	Adults
(Miscellaneous)	Scavengers		
	Predators		
	Accidental visitants		

Experiments in Hydrometer Jars, 1927.

The animals procured in the preliminary survey were kept alive, and were used in the first experiments. In the bottom of a number of glass hydrometer jars was placed absorbent cotton to a depth of three inches, with enough water to cover, and the jars were plugged with cotton and were sterilized in the autoclave as in bacteriological work. Pieces of seed-cane (one "eye" each) were treated with hot water (50° C. for one-half hour) and were introduced into the jars with sterile tongs.

Within a few days the cane sprouted and put out roots. The animals were placed in these jars and daily observations were made through the glass with the aid of a binocular microscope, the animals, roots and cane sprouts being plainly visible at all

TABLE II.

EXPERIMENTS WITH SOIL ANIMALS IN HYDROMETER JARS, 1927.

Number of Jars	Species	Number of Animals Introduced	Results After Two Months
3	*Zonitoides arboreus* Say	18	No pits
1	*Symphylella* sp.	5	No pits
1	Centipedes	3	No pits
1	Mites	Many	No pits
3	*Proisotoma minuta* Tull	8	No pits
3	*Lepidocyrtus violentus* Fols	9	Many pits
6	Checks	None	No pits

times. (See Pl. I, Fig. 4). In the two months that this experiment was running, root pitting and other injury was observed, but not in the jars containing snails. The springtail, *Lepidocyrtus violentus* Fols. was frequently seen in the act of eating typical pits in the roots. (Table II).

TABLE III.

SOIL ANIMALS IN PAILS, 1927.

Species	Number of Pails Used	Total Animals Used	Live Animals Recovered	Small Abrasions After 2* (or 3) Months	Results After 2 (or 3) Months
Zonitoides arboreus Say	7	89	15	3	No pits
Lumbricus sp. (small)	7	130	30	0	No pits
Lumbricus sp. (large)	4	72	36	14	No pits
Symphylella sp.	1	4	0	0	No pits
Centipedes	1	4	2	0	No pits
Millipedes, Brown	3	21	0	0	No pits
Lepidocyrtus violentus Fols.	7	208	Many	0	Manypits
Ptilodactyla larvæ	3	30	7	53	No pits
White Grubs (small)	1	4	0	0	No pits
White Grubs (large)	1	2	2	0	No pits
Fly Larvæ	2	9	1	0	No pits
Checks	10	0	0	0	No pits

*Where there were several pails containing a single species of soil animal, some pails were examined three months after "inoculation," as well as two months.

The experiments in jars, preliminary in nature and limited in scope, led to a series of tests of the soil animals with cane grown in galvanized pails in the greenhouse. The pails were filled with steam sterilized soil, were planted with hot-water treated seed cane, and the soil animals were added after the cane had germinated, (Fig. 8). A band of tanglefoot confined the animals in the pails, and prevented entrance of undesirable types. (Table III).

The results of the above experiments in pails confirmed the preliminary tests, so it was thought advisable to investigate more thoroughly the group *Collembola*, since the pit-making

TABLE IV.

SOIL ANIMALS IN PAILS, 1928.

Number of Pails	Species[1]	Average Results After Two Months			
		Growth of Cane Centimeters		Number Insects Recovered	Number of Pits
		Sprout	Root		
20	*Lepidocyrtus violentus*	64	273	158	144
3	*Onychiurus armatus*	79	213	174	30
3	*Orchesella ainsliei*	70	345	15	0
2	*Neanura muscorum*	87	216	0	0
1	*Proisotoma minuta*	0[2]	61	927	9
14	Check	74	238	0	0
5	*Symphylella*[3]	178	1559	20	156

[1]Fifty individuals of the species named, introduced into each pail.
[2]The "eye" failed to start in this pail.
[3]The average growth figures for *Smyphylella* should not be compared with growth in check pails, since these animals were added to pails at a much later date than were the other animals and growth had continued for a longer period.

Lepidocyrtus violentus Fols. belongs to that order of insects. In sugarcane fields *Collembola* of several species were collected in large numbers and were placed in a new series of pails and were handled as were the previous sets.

After a short time, a few pails were "inoculated" with the Symphylid *Symphylella*, because the preliminary tests with this species were too limited in numbers to be conclusive, and also the animals had shown pit-producing tendencies when fed small pieces of sugarcane roots in stender dishes. The results with pails containing *Collembola* and *Symphylella* are given in Table IV.

Root Injury ("Pitting") was produced by the *Collembola Lepidocyrtus violentus*, *Onychiurus armatus* and possibly *Proisotoma minuta*, and also by the Symphylid, *Symphylella*. In making examinations of the roots in these pails, the absence of the fine hairy side roots was strikingly evident in the *Lepidocyrtus* series; in addition to making many pits, the springtails ate off practically all of the side roots. This type of injury (named "Root Pruning" for convenience) is considered more serious than the pitting, since absorption of food and water must be greatly hampered by the removal of the secondary roots. (Plate I, Figs. 2 and 3). It will be noticed that the average root length of main roots, per pail, was greater in the *Lepidocyrtus* series than in the check series. This does not signify a stimulation of root growth by the insects, but is a growth response of the main roots, to this almost total destruction of secondary side roots by the springtails.

In the twenty pails containing *Lepidocyrtus*, the cane sprout growth averaged fourteen percent less than in the checks. This is a measure of the damage that might be attributed to the root pruning and root pitting by the springtails within an average period of about ten weeks.

In the cases of the pails containing the other animals, the averages should not be compared, as the number of tests is too small. They do, however, show ability or lack of ability of the animal to cause root pitting.

Relation of Soil Humus to Root Injury.

Even though the injury and growth reduction in the pails was not as extreme as often occurs in fields under outdoor conditions, the possiblity of lack of humus or other normal food in the pails forcing the animals to attack the roots, was considered. Four sets of pails were prepared, planted, and the animals were added as in previous work, but in one set was used sterilized field soil; in another, the same sterilized field soil with about 20% by bulk of sterilized partly decayed cane "trash" (leaves) added; in another the sterilized field soil with 20% sterilized soybean trash, and the last held unsterilized, air-dried field soil. Examinations after two months (Table V) indicated that an abundance of humus, of such kinds as might be found in fields of sugarcane, did not prevent or even lessen root injury by springtails:

At the present time, field experiments in large drums are being conducted, to ascertain the reduction in growth throughout the season due to the activities of soil animals alone, fungous diseases alone, and the two combined. In another series,

TABLE V.

RELATION OF HUMUS TO ROOT PITTING.

Number of Pails Averaged	Species*	Average Results After Two Months			
		Growth in Centimeters		Insects Recovered	Number of Pits
		Sprouts	Roots		
	SERIES A. STERILIZED FIELD SOIL.				
13	*L. violentus*.....	61	250	143	134
1	*O. armatus*.....	71	156	321	45
1	*O. ainsliei*.....	50	109	40	0
1	*N. muscorum*.....	94	226	0	1
5	Check.....	80	220	0	0
	SERIES B. STERILIZED SOIL AND CANE TRASH.				
4	*L. violentus*.....	71	182	288	201
1	*O. armatus*.....	63	174	170	29
1	*O. ainsliei*.....	75	347	2	0
1	*P. minuta*.....	0	61	927	9
2	Check.....	94	199	0	0
	SERIES C. STERILIZED FIELD SOIL AND SOYBEAN TRASH.				
3	*L. violentus*.....	66	491	51	111
1	*O. armatus*.....	104	309	31	16
1	*O. ainsliei*.....	86	580	3	0
1	*N. muscorum*.....	94	226	0	1
2	Check.....	31	187	0	0
	SERIES D. UNSTERILIZED AIR-DRIED FIELD SOIL.				
4	*L. violentus*.....	104	492	15	33
2	*O. armatus*.....	86	383	96	22
1	Check.....	97	842	0	0

*Fifty individuals in each pail.

applications of promising soil insecticides are also being made to sugarcane growing under plantation conditions.

The authors wish to express their thanks to Dr. W. E. Hinds who has made many helpful suggestions, to Dr. J. W. Folsom for identifying the *Collembola* and aiding in bibliographical work, and to Dr. C. W. Edgerton, Dr. E. C. Tims

and other members of the Plant Pathology Department, Louisiana Station, for wholehearted cooperation.

Summary

1. Root injury to sugarcane by soil animals is prevalent in all of the sugarcane parishes of Louisiana. Extensive examinations of roots and adjacent soil have disclosed a distinct group of "Sugarcane Soil Animals."

2. Experiments with soil animals in hydrometer jars and pails containing growing sugarcane have demonstrated that the root injury known as "pitting" is due principally to feeding activities of the Collembolans *Lepidocyrtus violentus* Fols., *Onychiurus armatus* Tull., and to a less extent by *Proisotoma minuta* Tull., and possibly *Neanura muscorum* Fols. Extensive "pitting" has been produced experimentally also by the Symphylid, *Symphylella* sp., but the Springtail *Orchesella ainsliei* Fols., and the snail *Zonitoides arboreus* Say and other members of the soil animal group did not pit the roots.

3. A type of root injury apparently more serious to the plants than pitting was observed, especially in experimental pails containing *Lepidocyrtus violentus* Fols. This injury has been named "Root Pruning," and consists of the almost total destruction of the secondary branch roots, by the feeding activities of this springtail.

4. In one test, with numbers of pails sufficient to give dependable averages, sugarcane sprout growth was reduced fourteen percent in the first eight or ten weeks in pails containing *Lepidocyrtus violentus* Fols., as compared with similar pails in which there were no springtails.

5. The presence of an abundance of humus in greenhouse experiments with the springtails in pails, did not prevent injury to sugarcane roots.

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EXPLANATION OF PLATE.

Soil Animals Injurious to Sugarcane Roots.

Fig. 1. Roots of sugarcane from field, showing pits produced by soil animals. (Photograph courtesy of Dr. C. W. Edgerton).

Fig. 2. Roots of sugarcane grown in greenhouse in pail in which were many specimens of the springtail *Lepidocyrtus violentus* Folsom.

Fig. 3. Roots of sugarcane from a similar pail, not containing springtails.

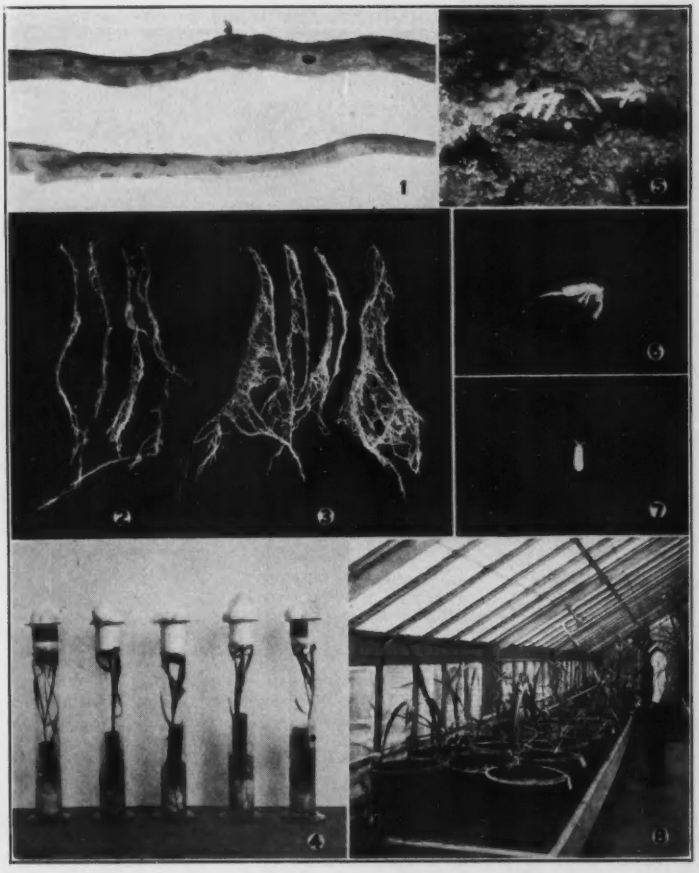
Fig. 4. Hydrometer jars in which pieces of sugarcane were grown, to observe feeding activities of various soil animals.

Fig. 5. Young specimens of *Symphylella* sp., and one egg unhatched, in "nest" in soil, greatly enlarged.

Fig. 6. Adult *Lepidocyrtus violentus* Folsom, much enlarged.

Fig. 7. Adult *Onychiurus armatus* Tull., greatly enlarged.

Fig. 8. Sugarcane growing in pails of sterilized soil, containing soil animals.



THE REARING OF DRAGONFLIES FROM EGGS.*

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In working out the life history of certain trematode parasites which occur as adults in vertebrate animals it was necessary to rear parasite-free dragonflies which serve as intermediate hosts in the life history. Since parasitologists have to rear hosts which are free from certain kinds of parasites at least, it makes the problems of food and feeding more difficult. The literature on the subject of rearing common, well-known species of invertebrate animals in the laboratory is scarce and there is an increasing demand for such knowledge; so that the author deems it worth while to make this information available. The following excerpts are from Needham and Heywood ('29, p. 239): "Some eggs obtained in September at Ithaca hatched the following January, having been kept the while in a laboratory of the normal temperature. Doubtless under normal conditions they do not hatch before spring." "Mr. F. R. Nevin has raised vicinum from eggs, laid on October 1 by females from this same pond, which hatched, indoors, from November 28 to January 4 and yielded imagoes on May 3 to May 10, after 11 larval instars."

COLLECTING AND HATCHING.

The species of dragonfly used in this work and which the author had occasion to rear in the laboratory was *Sympetrum obtrusum* Hagen. The eggs were collected while at the University Biological Station during the summer of 1928.

The method of oviposition is of the exophytic type, consequently the eggs are of a rounded form. The average length of the egg of this species is 0.56 mm. and the average diameter 0.49 mm. When the eggs are laid they are of a light yellow color, but later most of them turn dark brown. Some of them retain the color which they have at the time of deposition; in these the progress of development can be observed and the

*Contribution from the Zoological Laboratory and the Biological Station of the University of Michigan.

eggs hatch as well as those which change color. According to Tillyard (1917, p. 227) the species in the genus *Sympetrum* lay their eggs in gelatinous ropes, but such is not true in this species.

Early in the season a locality was found about three miles from the Biological Station, on the shore of Burt Lake, where this species occurred in great numbers. At the height of the season, the middle of August, eggs were collected by catching insects which were *in coitu*.* In obtaining eggs the female was grasped quickly by the wings and if she had not already laid all of her eggs they began to appear very shortly in pairs, side by side, at the genital opening. The eggs were collected by holding a dram vial containing clean tap water or swamp water underneath the insect. Sometimes the eggs were very dry and dropped immediately into the vial. At other times they were somewhat sticky, adherèd together, dropped in masses and separated when they struck the water. It appears to me that the males aid the females in egg deposition and that the eggs are dropped while the insect is flying or while resting on sedges. I have never seen them strike the water but they generally fly several feet above it. Tillyard (1917, p. 358) states that in collecting eggs the abdomen of the female is placed in water in the vial. The author was more successful in obtaining eggs by keeping the abdomen of the insect out of water.

The eggs were kept in these uncorked vials for several days, transported to Ann Arbor, Michigan, and there they were transferred to Syracuse watch glasses. Most of them were put into clean water, some into dishes containing mud and water, others into clean sand and water. The watch glasses were stacked or covered to prevent evaporation. Tillyard (1917, p. 358) states emphatically that the water in which the eggs are kept must be dirty or the eggs will mold. Eggs which were kept in clean water hatched the best, the newly hatched nymphs were more easily seen, and could be removed with greater ease than from the other dishes. Fungous growths, to be sure, appeared but did not interfere seriously with hatching; they were kept down in some dishes by changing water occasionally, and to several dishes enough salt was added to make a strong salt solution and the eggs left in it an hour or

*Defined as merely a union of sexes.

so; this I found later did not interfere with hatching but kept down these various growths. Oil appeared on the surface of the water in the dish containing mud and decaying organic material. The water was changed several times on this account. In this connection Tillyard (1917, p. 358) states, "Decaying vegetable matter seems to be essential. I have never succeeded in rearing eggs kept in pure water."

Eggs collected on August 14 and 15, 1928 began to hatch on October 9. I found one nymph in each of three dishes on that morning. Nymphs were removed night and morning. There was no marked difference in the number which hatched at night and the number which hatched during the day. Eggs were kept in the laboratory out of the sun's rays. They continued to hatch until January 30, 1929. According to Tillyard (1917, p. 358) the rounded eggs hatch in from five days to three weeks which seems to indicate that this species is rather exceptional. Some of the eggs were kept in a room which had a temperature of 60° F. or below and they did not continue to hatch any longer than those kept at room temperature or above. The majority of the eggs hatched. Some of the dishes containing eggs which were hatching were put into a cold room kept at a temperature of about 45° F. They ceased to hatch at this temperature and nymphs could be secured when they were wanted by taking the dishes containing eggs into a warm room for a short time. The experiment was concluded when on January 30, 1929, I discovered that the ice machine had failed, the temperature had risen, many eggs had hatched, and most of the nymphs were dead. This happened some time during the month of January. The few remaining eggs continued to hatch until February 27, 1929. At the present time, June 10, 1929, the author has some of these nymphs; they are as strong and transform as well as the others. Eggs collected August 11th and 14th, 1928, were placed in an outdoor, artificial, cement lined pool on November 21, 1928. The pool is small and about eight feet deep. The container for the eggs was made by removing the bottom from a two dram vial and covering each end with three layers of silk cloth. The eggs were removed from the pool on March 18, 1929, one day after the ice had melted. None of the eggs had hatched, but all of the nymphs were out within two days after they were brought into the laboratory.

Nymphs make their escape from the egg very quickly and undergo an ecdysis immediately. I have managed to catch them in various stages of these processes, placed them under microscope, but without removing them from the dish and in every case the nymph made no more progress. It is quite likely that the light effects them or that they cannot be disturbed during this time.

Growth

Of nine nymphs on which specific data were kept eight transformed in nine instars* and the remaining one in ten. Tillyard claims that the number of instars for nymphs in general varies from 11 to 15 inclusive. If this is true the number for *Sympetrum obtrusum* Hagen is small. Growth curves which were kept on several nymphs show that the rate of growth increases very rapidly with the increasing number of instars. The average length (twenty-five specimens) of a nymph after the first ecdysis was 1.31 mm., the longest was 1.62 mm., the shortest 1.17 mm. The average length (thirteen nymphs) of a nymph after the second ecdysis was 1.57 mm.; the longest 1.7 mm., the shortest 1.45 mm. The average number of days in the second instar (fifty-one specimens) was six and one-half, the maximum twelve and minimum four and one-half; the average number in the third instar (thirty-four nymphs) was five and one-half, maximum nineteen, minimum four and one-half; the average number in the fourth instar (thirty-nine specimens) was six, maximum eight and one-half, minimum four; the average number in the fifth instar (thirty-four nymphs) was five and one-half; maximum ten, minimum four and one-half. For the sixth, seventh, and eighth instars the figures in their respective order are as follows; seven, nine, five (thirty-two specimens); seven, eight and one-half, six (twenty-six nymphs); eight and one-half, eleven, six (eighteen nymphs). The average number of days between the eighth ecdysis and the transformation (eight specimens) was twenty-one and one-half, the maximum number was twenty-two and one-half, the minimum eighteen. The nymph which required ten instars transformed seventeen days after the last ecdysis. The wide range in the number of days in the third

*I am following Tillyard in considering the pro-nymph as the first larval instar.

instar reflects upon the difficulties in getting suitable food. This is a critical period during which the nymph changes from a diet of *Paramecium* to the nauplius and metanauplius stages of *Cyclops*.

Food and Rearing

Nymphs can be reared on two kinds of food but it requires a great deal of patience, time and effort. In this case the nymphs are first fed on *Paramecium* and transferred to tubificid worms (Genus *Tubifex*) in the third instar. In feeding these very small nymphs, the smallest worms have to be cut up and only the ends used in feeding. By adding *Cyclops* to the above foods one has an ideal combination.

For rearing *Paramecium* I employ the method used by Dr. A. E. Woodhead of this laboratory. A very small amount of crumbled dry bread is added to a one-half pint fruit jar, the jar is filled with tap water and inoculated with *Paramecium*, then covered and put on a shelf out of the direct rays of the sun in a rather cool place. For keeping a supply of tubificids I use the method employed by Professor George R. La Rue of this laboratory in his course in laboratory methods. Muck known to contain tubificids is gathered from the shore of a lake or bank of a stream and put in pans which are 18″ x 12″ x 3″. The pans are filled about two-thirds full, and a small continuous stream of water running into the pan keeps the worms sufficiently aerated. About every two weeks it is necessary to bury boiled potato or pieces of raw lettuce cores in the muck. This feeds the worms and concentrates them so that they are easily removed for feeding purposes. Thus they can be kept the year round. The method of rearing cyclops has been more or less of a hit and miss affair so that it is impossible to give a formula, unless one uses the method given later. Dr. D. L. Gamble (1929) gives methods for rearing *Daphnia*, which probably could be used in place of *Cyclops*.

It saves time and trouble to put nymphs in individual containers at the time of hatching, although they may be kept in the same container until about the fourth instar, but after that those nymphs which survive show the scars of many battles. I have reared nymphs until they were half grown in Syracuse watch glasses. When reared in such a limited environ-

ment the water as well as the food must be changed at least every other day. If they are well fed they moult often enough to keep ahead of the fungous growths and protozoans which accumulate on them. A lowered temperature reduces difficulties immensely. Using different kinds of water helps in keeping down these growths; for instance, one day I use tap water; the next, rain water; and then filtered water. A few grains of sand in the dish aid the tiny nymph materially in capturing its prey for without it the impetus of thrusting out of the labium sends the entire nymph back so far that the *Paramecium* or *Cyclops* escapes. Nymphs must not be disturbed during ecdysis or immediately after; if they are they usually do not complete the process or the appendages are crippled. After they are about half grown it is best to put them in large individual containers; two-quart fruit jar is very satisfactory. It is prepared for the nymph by putting two inches of clean water in it, to which is added three or four coarse pieces of grass stems* which have been previously soaked in water so that they sink readily to the bottom. A *dry* (free from sap) rough weed stem about 3 or 4 mm. in diameter which reaches from the bottom to the top is also added before the nymph is dropped into the container. It is well to clean the sides of the jar thoroughly prior to the time of transformation so that the nymphs cannot climb. If this is not done they climb the wall of the jar to the surface of the water when ready to transform and drown. Growths of filamentous algæ should be removed because the nymphs die or become tangled in them. The top of the jar is covered with a piece of mosquito-netting fastened by a rubber band. Usually the nymphs metamorphose on the stick about three inches above the water (which is usually true in nature although they climb much higher at times) and then climb up and hang from the netting. At other times they climb up and transform on the netting. The water can be poured out through the cloth without disturbing the teneral adult if one is careful. The percentage of successful transformations is greatly increased and the teneral adults live much longer if they are given plenty of food from the time of the last ecdysis until they stop taking it prior to metamorphosis. Teneral specimens

*Dried grass before it is soaked.

have been kept alive four days. The rate of development of the nymph can be retarded by governing the food supply. In doing this, however, it is much better to feed the nymph a small amount daily rather than allowing it to go without food for several days.

If one is not particularly interested in specific data on individuals the nymphs can be reared in the following way without any effort on the part of the keeper and at least seventy-five percent of the nymphs reach the adult state. The two quart jar should be prepared according to the directions above, but in addition to these materials add 15 or 20 cubic centimeters of concentrated *Paramecium* from a clean* culture, six or eight mature *Cyclops* (preferably those which bear egg sacs), and finally the newly hatched nymph. Keep the nymph in a cool place.† It is well to cover the jar to prevent evaporation. By this method a natural food chain is established which is supported by the pieces of grass stems. During the early stages of development the nymph is aided in keeping itself clean, no doubt, by the mature *Cyclops* for they may be seen apparently feeding on the surface of the nymph. It is well to watch the jars because sometimes they have to be replenished by adding *Paramecium*.

The nymph can be removed from the container by shaking it and pouring the contents out into a suitable receptacle. This does not injure the nymph for they can stand rough treatment. Tillyard (1917, p. 358) says that the nymphs should be handled with a camel's hair brush. This is slow and tedious. A very small nymph is easily and quickly handled without injury by picking it up with a pipette which has a suitable opening. Older nymphs can be handled by the legs with a pair of fine forceps. An instrument still better for handling nymphs of all sizes is made by making a loop three-fourths of an inch in diameter from coarse copper wire. Twist the ends of the piece of wire together for a handle and make it as long as desired. Stretch a piece of coarse bolting cloth across the loop and sew it to the wire. Since the frame is made

*It is absolutely essential that one gets the minimum amount of organic material and it is therefore best to take *Paramecium* with a pipette from the regions in the culture where they are most concentrated.

†I have been keeping them in a room which during the winter months has a temperature of about 60° F. during the day; it gets much colder at night, but never freezes.

out of copper wire the angle of the loop in relation to the handle can be changed to suit particular needs.

In rearing nymphs a number of different methods have been tried which include different kinds of containers, and different kinds of foods but the methods described above have given the best results and, no doubt, they can be used very well on many of the smaller forms.

I wish here to express my grateful appreciation to Professor Clarence H. Kennedy, Ohio State University, who has given me information concerning the bibliography and methods of feeding and handling dragonfly nymphs; to Dr. C. Francis Byers, University of Florida, for the identification of specimens; and to Professor Paul S. Welch and Professor George R. La Rue for suggestions in the preparation of this paper.

NOTE.—Since this paper was sent to the editor an article by Nevin on the "Larval Development of *Sympetrum vicinum*," (Trans. Amer. Ent. Soc. 55: 79–102) has appeared.

Comparison of his data on *vicinum* with mine on *S. obtrusum* shows that the embryonic period is about the same when eggs are kept under similar conditions, and that the period of time during which eggs hatch is much longer for *obtrusum*. The number of instars in *obtrusum* is less; is constant for *vicinum* (four specimens) and variable for *obtrusum* (nine specimens). When more *vicinum* are reared the number of instars may also be found to be variable. In comparing growth curves (unpublished) one notices that the increase in length of the *obtrusum* nymph (three specimens) in the early instars is more gradual than in *vicinum* and that the greatest increase in size takes place in the last instar in which the nymph gets more than one-third of its growth (one specimen). Nevin was unable to collect nymphs of *vicinum* in the spring and early summer from a pond in which they were supposed to occur. I collected nymphs from a pond near Ann Arbor, Michigan, on April 30, 1929. Judging from their size they were in the third instar. They transformed in the laboratory and proved to be *obtrusum*. This fact and my experimental evidence indicate that some of the eggs hatch in the early spring.

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THE NESTING HABITS OF THE BALD-FACED HORNET, VESPA MACULATA.

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It is a surprising fact that, despite its wide distribution and the conspicuous size and formidable appearance of both insect and nest, this wasp is comparatively little known. The fact that so little work has been done on the behavior of this species is doubtless due largely to three reasons: first, most investigators are strangely prone to be indifferent to those familiar things about them which they feel everyone knows by hearsay, and thus good material at our very doors is often neglected for something more novel or unknown; second, the formidable attitude of this hornet, and its reputation of long standing, do not invite scientific scrutiny; lastly, their habit of building nests high up out of reach or in positions where a hasty retreat cannot be effected in case one is suddenly overcome by a strange impelling desire to be elsewhere, is not conducive to intellectual calm or physical repose. While the following account gives us only certain phases of the life history of this hornet, it will in some measure fill a gap.

I have been fortunate in finding the opportunity to observe the very early stage of nest-building, when the queen single-handed acted as home-builder, mother and provider, and to follow the process in another nest built so low to the ground that I could approach within a few feet of it.

On an abandoned trestle (Fig. 1) in the old stone-quarry at Wickes, Mo., I chanced to see a queen intently occupied with a protuberance on the under side of a beam. It was the beginning of her new nest. The wasp was bringing in pellets of paper pulp and increasing the size of the nest. It is significant that for the most part she alternated in the application of her pulp; she would bring in a load and apply it to the covering, then take the next load inside the nest, presumably to build combs. The detail records show, however, that this alternation was not infallible; there was, as always, variation in her work.

However, her trips to and fro as she worked were very regular, almost rhythmical, as follows:

4:20—Left the nest.
4:25—Returned with pulp and went into nest.
4:28—Flew away.
4:33—Returned with pulp and remained inside 12 minutes.
4:45—Flew away.
4:52—Returned with pulp, entered for a moment, then came out and applied pulp to cover; then went inside.
5:00—Flew away.
5:08—Returned with pulp and went inside nest.
5:24—Flew out and away.
5:30—Returned and went inside for a few seconds; then came out and applied pulp to cover.
5:33—Went inside. I had to leave until the next morning, when at
7:50—She was spreading a layer of pulp on the cover.
7:52—Departed for the fields.
7:59—Returned and took pulp into nest.
8:10—Flew out and away.
8:17—Returned and went inside with pulp. I had to leave until
8:43—When she was again found inside.
8:45—She left.
8:55—Returned and went inside.
9:08—Departed.
9:15—Returned and went inside for a few seconds; then came out and applied pulp to cover.
9:18—Went inside a moment, then flew away.

Thus the number of minutes spent in her trips for getting pulp varied as follows: 5, 5, 7, 8, 6, 7, 7, 8, 7. The number of minutes she spent on applying the pulp to the cover of the nest ran 2½, 2½, 2, 2½. The time she spent at unknown work inside, including the disposition of the pulp which she took in, was 3, 12, 5½, 16, 11 and 15 minutes. Thus the deviations from regularity were practically all in the privacy of her own house, where I dared not be too inquisitive.

This nest was of course made entirely by the queen. Undoubtedly beginnings like this are completely wrecked and made over when they are later enlarged by the workers. A paper cover completely enclosed the tiny combs, and the beginning of another paper covering was apparent; this was being added to from time to time. At first glance one suspected that the complete covering was the first, and the unfinished layer the second covering in the work. By aid of mirrors carefully manipulated during the queen's absence, I examined

the inside of the nest, and the total of what I saw was surprising. There was a little comb of ten cells, very similar to *Polistes'* cells, and at least one egg could be seen attached to one of the walls. Around this hung a curtain of paper about an inch in length. Just outside this circular curtain was a second layer of paper, quite independent of the first and having an average space intervening between this and the first of probably one-quarter inch. This second layer extended down lower than the first, and was one and one-half inches long. The third layer (then the outer complete one) was also absolutely independent of the second, and extended below it, being about

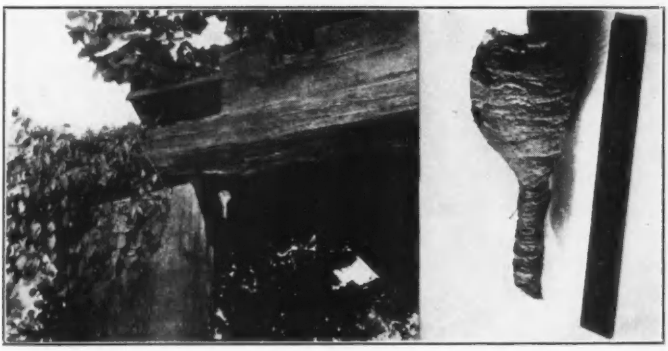

Figure 1 ***Figure 2***

Fig. 1. The nest of *Vespa maculata*, the sole work of a queen.
Fig. 2. A close view of the nest shown in Figure 1.

two and one-fourth inches in length. The fourth layer, also separated from the third layer by an intervening space of one-fourth inch, was the incompleted cover at that time, and was only one-half to three-fourths inch long.

It would have gratified me to witness the very first work done on the nest, to learn whether the cells were made first and the cover put on later, or whether the protecting cover was first built and the cells placed later. It would be quite an architectural feat to build a complete circle of pulp and then fit the cells inside. Furthermore, if the work went on at the start as it was being done when it was discovered, with a load of pulp for the cover and then alternately a load for the cells, it would be hard to account for the origin of the instinct leading

to this form of nest. If the cells are made first, one would suspect that this is a *Polistes* habit, with only the addition of the sheets of paper covering; this would put *Polistes* in the position of a more primitive form. If, however, *Vespa* is actually the more primitive, then one must say that the higher form, *Polistes*, has lost this habit.

A pin stuck into the unfinished cover on the occasion of the discovery of the nest, May 28, showed on the next visit, June 13, that, as I expected, this cover had been extended completely to envelop the nest, and had even been carried beyond it and narrowed down into a hollow tube with the opening at the bottom (Figs. 1 and 2). This tube was ½ inch in diameter, and 2½ inches in length, beyond the body of the nest. The top layer was, as we have seen above, the fourth covering; at the top of the nest, next to the supporting beam, the fifth layer was at that time being begun. Up to this date no workers were present; the queen was the sole inhabitant and worker.

On the morning of June 18, I found three workers present. A small window was carefully cut in the wall of the nest, to reveal the interior construction. Imagine my surprise when I found that the curtain-like covers 1, 2 and 3 had been entirely removed, and covering number four, with the long tube, was now the only one shielding the combs! The old covers had evidently been rechewed into pulp to finish the fourth cover with its long tube. The number of cells within had increased greatly; many were capped, some had larvæ so far grown that they protruded from their cells. One lone worker remained and for the day and a half when I could watch her during the queen's absence, never left the nest; in fact, she made no attempt to repair the rent. With her foot she often pushed back into their cells the hungry, protruding young. Earlier in the morning, before the queen and two workers were taken. I could see the queen and young workers clearing out the old cells from which these had hatched; in fact my eye was once too close under the tube when a load of wet debris was flung down into it. This occurred at six o'clock in the morning; they began their day's work early.

Since further observation had been spoiled by the failure of the queen to return from her enforced journey, I took the nest. Figure 2 shows the queenly workmanship, alongside a five-inch rule.

Another nest of *V. maculata*, plump and round and about three-fourths full size, and with a thriving colony, was discovered in mid-summer. This was attached to an elm shrub, three feet from the ground, and only a few feet from the road, where many a horse and pedestrian was given a merry chase. Since all of the queens begin nest-building at about the same time in the spring, one can imagine this colony (Fig. 3) as being almost a replica of what the nest in figure 1 would have been on July 21 if I had not taken it. In others words, the story that we may logically deduce from figures 1 and 3 is that

Figure 3

Fig. 3. A half-grown nest of *Vespa maculata* in an elm shrub.

the nest which had on June 18 three newly hatched workers would have grown in thirty-four days to the proportions shown in figure 3 with its populous and active colony

The nest was a-hum with activity; wasps were coming and going, some to the south and southwest, others going north. There were at all times from three to six wasps at the entrance, occasionally one or two at the top near the point of attachment to the twig, and from one to three working on the unfinished covering. This sheet now reached down midway on the nest, and new paper was being added to it. The opening was not at the very bottom as usual, but was about two inches above that point and faced northward. Three layers of paper were visible at the entrance, and these served as a fine floor or

landing platform. The opening itself was about three-fourths inch in diameter.

The wasps which flew in were probably carrying pulp or water, but most of them flashed by so swiftly that one could not see whether they were empty-handed or not. One, which was heavy-laden and traveling more slowly, was carrying in a large brown caterpillar under her body. This was intact, thus dispelling the notion that they carry their food in piecemeal. I could not venture close without causing some commotion. One gave me a slight sting on the arm, the sensations of which lasted about fifteen minutes. The others kept me on the run more times than I care to mention. How these wasps discover an enemy is, in fact, strange and interesting. One can stand still as a stick, thirty-six inches from the nest and watch them fly in over his head or past his face, for a considerable time without attracting the slightest notice. Suddenly one out of the multitude will spy the intruder or in some way sense his presence, and go buzzing around his head in audible circles. It has every opportunity to sting, but it does not do so. If the visitor becomes too ill at ease and begins to run, the disconcerting buzz follows him, seemingly, in "sounds in circles." One can always outrun a sting, as repeated trials have shown; the workers will seldom follow one more than a hundred feet. One often thinks, when watching a nest with impunity despite the fact that workers are passing in and out, that he is unnoticed; suddenly one wasp seems to size up the situation and puts the intruder to flight. It would seem that certain individuals in the nest are especially endowed or trained to be guardians of the home. It is especially surprising to me that the boisterous buzzing going on about one's head at such a time does not attract the whole swarm to join in pursuit. I do suspect that the news is transmitted somehow when the fighter returns, because when I creep up slowly after a flight, I find the doorway crowded with a dozen or more excited individuals, whereas previously only two or three were at the gateway.

It was my privilege to see the first four workers of the first brood emerge from the nest made by the queen alone on June 18, (Figs. 1 and 2). These workers looked exactly like the queen mother and the other workers, only they were of about one-half the normal size of workers; in fact, they more

resembled in size the workers of *V. germanica*. The workers in the large nest were all of about the usual size, or about twice as large as any of the first four which had emerged from the queen's nest. It is a problem yet to be solved, whether size varies with the activites in the nest, or whether the first to emerge are usually small because of their inadequate nutrition that must naturally occur when the queen has all the work to do alone.

At the time of discovery of this nest on the elm shrub, (Fig. 3), the unfinished outer layer of paper extended less than half way down the nest. In three days this entire covering was completed and the beginning of a new one, a ring of paper around the top of the nest and an inch in length, was made. From this one can get an idea of their industry, when one considers the small mouthfuls that they carry at each load and remember that only two or three, and never more than half a dozen, are occupied at paper making at any one time. The secret of their success lies in their ability to make a mouthful spread a long way. With their pliers-like jaws, they pinch the ball of pulp until it makes a thin, narrow strip almost an inch in length. The long hours that they spend at their work and the easy accessibility of their materials are also factors in hastening their work. As the text-books tell us, their pulp is usually made from rotting wood, but I have seen a few taking advantage of the supply of ready-made paper with which our modern civilization strews the woods. Of this I am certain, for after the wasps had left, the spots showed clearly where the material had been freshly scraped away.

By September 2, this nest had increased noticeably in size and strength of colony. During the night, I removed it, in order to get an accurate census of the population and an account of the nest as it was at that time. Under cover of the darkness, and armed with a scrub-bucket, a gunny-sack, a rope, a knife and a cord, and with a small son to assist, we made our way down the rocky hillside through the woods for a mile, to where the hornets were in calm repose.

Now when one examines a hornets' nest at night, one finds the outside clear of guards, but just within a few may be seen, which emerge drowsily at the first gleam of the flashlight, but they do not give the alarm. I approached the nest stealthily and stood for many minutes pondering just what course to

follow. To stand thus, moment after moment in the very presence of so powerful a population, where one would never think of approaching during waking hours, is in itself an event not without emotions of its own. The portrayal of the tense moments of anticipation and self-compulsion, I shall leave to Lady Macbeth: "But what hath made them drunk hath made me bold! * * Infirm of purpose! Give me the daggers!" I carefully survey the structure of the nest, and note that it is attached by three twigs; I will cut two of them, and when the suspicions of the disturbed sleepers have again subsided, I will place the pail beneath, cut the third twig and run, and when I return with sack and cord, I shall find them snug within the pail. I signal to the boy to go down the road about fifty feet with the lantern, and by the aid of my flashlight I cautiously snip the first twig. An explosion of buzzing occurs within; many come to the aperture and crawl outside, while the buzzing within swells like the rising wind before a sudden storm. I darken the flashlight and wait * * * More emotions. * * Who ever said that time has wings? * * Why *will* that bucket handle rattle so? Crackle! Here through the underbrush comes an inquisitive dog to greet us—confound that pup! The deep rumble within fitfully subsides. I cut the second twig. The great ball quivers for a moment while the occupants, already alert, pour out of the aperture like hot lava from a crater. Crash! The remaining twig breaks under the ponderous load, and the mass crashes to the ground! Both the hornets and I were then guided by pure instinct; the dog was more faithful to his investigations—alas!

Having eventually discovered myself somewhere down the road, I began considering how to finish the task. Stealthily slipping the lantern back near to the scene of the disaster, so that the stragglers could see to return to the nest, we walked again to headquarters and obtained a rake, and an hour later with perfect ease I raked the mass into the bucket, covered it with the sack, and carried all back to the city on the train the next day amid calm and unsuspecting fellow passengers.

There are important details which need to be mentioned here. The next morning when I went to examine the site, I found that in rolling the nest with the rake, a piece of the outside layer of paper about as large as one's two hands, had been torn off and lay on the vegetation three inches from the

ground, and that about fifteen very vicious workers that had been left behind or had been out all night, were clinging to the under side of this remnant of what had been their home. I was delighted to find, upon returning exactly a month later, October 2, that this remnant of the colony had constructed a new nest, using as a foundation this one sheet of paper, supported on a bed of weeds, three inches from the ground. This nest was very different from the former one in both shape and size. The original sheet had been used as the roof and the nest had been built below it. This work was undoubtedly the achievement of the workers only, because the young queens were not abundant in the nest, and in the small combs within this second nest, which I shall later describe, only a few larvæ were in evidence and they had all died while they were very small. No queens were found in the nest on the occasion of this second visit, and only ten workers remained. It seems unlikely that unfertilized queens* could or would build nests of a different type of architecture from that usually followed by the species. This nest displayed paper material in more than half a dozen shades of grays and browns, and at the point where I had cut a window in the wall there were six layers of covering. The interior was very irregular, showing bumps and lumps, due to the fact that the wasps made the best use they could of the foundations which they had at hand. The opening to the nest was only a tear made by the rake in the original scrap of paper, and was a very crude aperture. One can hardly give the dimensions of this shapeless mass.

Not satisfied with making for themselves a shelter only, these industrious workers had made two combs of shallow cells, one with 12 cells, which was fastened to the ceiling of the nest and one with 10 very small cups; the latter cluster had fallen to the floor of the nest, but in three of its cells were tiny dead larvæ.

The accidental experimentation reveals the plasticity of these creatures; if they have no home, they make one, even though the season be near the end. If they have no twig, they make good use of a weed or any available material; and since the workers carry eggs, they build combs, lay eggs and try to rehabilitate the colony.

*No males were in the nest when it was taken on September 2.

The entire mass of the first nest was taken home and etherized; care was taken to see that all the adults died under the ether, but the young in the capped cells were uninjured. The nest with these sealed cells was placed in a breeding cage and from it healthy adults emerged from time to time. Those which emerged were kept alive by feeding upon molasses, grape jelly and canteloupe; when water was sprinkled upon the nest, they lapped up great quantities of it. A census of the adults in the nest on September 2 was as follows:

Killed adults, workers	220
Killed adults, queens	34
Workers left behind	15
Total population, September 2	269

There were four tiers of combs in the nest; the lowermost was the smallest, with only 12 cells, 8 of which had eggs. The cells of the other tiers could not be counted without the utter destruction of the nest, but I could see that the third tier contained 51 sealed cells, and the second a considerable number. During the next thirty days, adults emerged from these capped cells to the number of 88 workers, 52 males and 85 queens. This gave us an entire adult population at the end of the season of 494, of which 24 per cent were queens. It is true that in their natural environment, a number of the larvæ would have been brought to maturity. Our first deduction is that this would have increased the population; very probably, however, some of the adults would have died during the interval, so one is justified in assuming that the number 494 is approximately correct for this nest at the end of the season.

With almost all nature books telling us that in the autumn both males and queens are born, it is highly interesting to review the figures of the census given above to find out just when the reproducing organisms come upon the scene. These figures show that on September 2, when the entire population was anaesthetized, there were absolutely no males—only workers and queens; evidently the latter were just beginning to appear. But during the next thirty days the adults that emerged from the capped cells numbered 225, of which 85 were queens and 52 were males. It showed at least that the queens emerge earlier than the males, which is somewhat different from the condition in most insect life, since in many

solitary species priority in male emergence occurs. It also shows that the nest as a whole gave birth to 119 queens and only 52 males. This disproportion of the sexes is, however, probably due to the fact that the combs contained many larvæ which died under the severe conditions of being caged, and, since the males were the last to emerge, a greater proportion of the larvæ that died were naturally those that under natural conditions would have developed into males. This would have equalized the sexes, or perhaps left the males predominating.

I have no way of knowing how long the new queens had been out, but I often wonder if it is not possible (although perhaps improbable) for these virgin queens to oviposit in the cells and thus produce males before the end of the season. I do not fully know the literature on this subject, but it seems to me that this explanation of parthenogenesis is just as logical as the explanation that a fertilized female can, by contortions or otherwise, pass from her body eggs which have escaped contact with the fertilizing element. Of course this can in part be proven in a future season by examining the abdominal contents of a few queens in the fall to ascertain if they contain mature eggs at that season.

A later examination and dismemberment of the nest revealed that the number of cells in the four combs was as follows:

Tier	*Old or Capped Cells*	*Total Cells*
First or top comb	375	375
Second	380	572
Third	54	180
Fourth or lowermost	0	12
	809	1,139

These figures are of interest in showing that the number of cells built was 1139, of which 340 were new and too small at the end of the season to have permitted an adult to come to maturity, while 809 cells gave strong evidence of having brought at least one occupant to maturity. I did not make careful count of how often cells were used a second time, but we know that from these 809 cells there remained at the end of the season a population of 494.

It is often remarked that cells are used more than once; this can easily be ascertained in this way. The larva feeds

during its life and carries the excrement in its body until just prior to pupation, when it ejects it all at one time; since the larva hangs head downward, this material is plastered against the roof by movements of the body, and eventually hardens into a reddish-brown, gritty substance. By counting the number of layers, one can easily tell the number of occupants of a given cell. This same statement applies to certain and probably all species of *Polistes*. Unfortunately, this examination of the layers of excrement in the cells of this nest was delayed until too late; the dermestes larvæ had so far destroyed the cells as to make counting impossible.

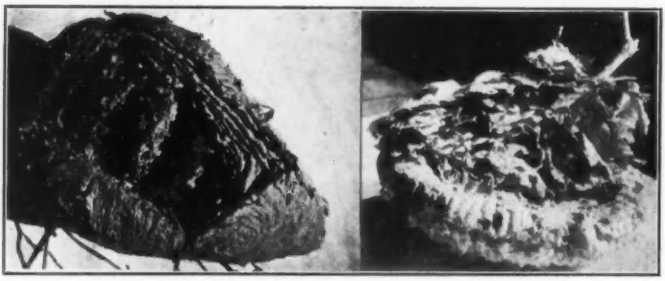

Figure 4 ***Figure 5***

Fig. 4. A nest of *Vespa maculata* with covering removed to show the combs.
Fig. 5. The attic in the nest of *Vespa maculata*.

Not all that are born survive, and despite the formidable demeanor of these hornets, we have some records of their falling prey to other animals. Bilsing* fed *V. maculata* to the spider, *Phidippus audax*, and Bromley† records that this wasp was preyed upon by the robber-fly, *Proctacanthus philadelphicus*. We know they are persecuted by man wherever he has the courage to attack them, but we are surprised to learn that in some places men also eagerly gather all they can find for food. Cowan‡ tells us that the Creoles of Mauritius eat the larvæ of these wasps, after having roasted them in the combs. In taking the nests, they drive off the adult wasps by means of a burning rag fastened to the end of a stick. "The combs were,

*Ohio Journ. Sci. 20: 257. 1920.
†Psyche 21: 194. 1914.
‡Curious Facts in the History of Insects. 1865.

at his time of writing, offered for sale at the bazaar of Port Louis."

It is interesting to note that the large cells from which the queens had emerged were not isolated, but were scattered promiscuously throughout the two central combs. Several of them gave evidences of being old cells now reoccupied. The same condition was found in another large nest which had three tiers of cells, and in all three were the large cells of the queens scattered at random among the others, showing also old cells reused. Some of these larger cells may be seen in the three tiers shown in the illustration; (Fig. 4), here one wall is cut away to reveal the inner structure and the six layers of paper in the covering.

The queens of *V. maculata* do not hibernate in the old nest, but find shelter for the winter elsewhere. On October 22, 1922, two females of this wasp were found hibernating under a log. Each was in a small cavity in the under side of the log; they were about three feet apart.

When one walks into the woods and sees high up among the branches a nest of *V. maculata* swinging lightly with the breezes and resembling some huge tropical fruit, (Fig. 10), one scarcely realizes that it has the stability to withstand the vicissitudes of the weather. But these artisans build strong, as the few details below will show.

The first comb is very securely fastened on a stout twig, and between the roof of the comb and outside paper covering is a mass of stout, irregular layers that hold this comb to the twig by the increased strength of many points of attachment, both to the twig and to the nest. This somewhat resembles corrugated cardboard (a cross-section may be seen in figure 5; it combines lightness with strength, but its main feature is its rigidity. Regardless of how the wind and weather may tear the outer cover, this first comb is anchored rigidly to the twig and the safety of the young in the cells is assured; it is a small matter to repair a rent in the roof. Before going on with further details of this nest, I want to introduce a photograph (Fig. 6) of a last season's nest just as it was removed from the tree. This nest had survived the rigors of a Missouri winter. The covering was torn and tattered but the combs adhered securely to the twigs. This demonstrates the advantage of their type of building. Many people have the notion that the

combs adhere loosely to the interior of the paper walls, but an inspection of the interior of any nest proves the contrary.

The reinforcing layer which is built in between the top comb and the support varies in thickness; while in some places it is as thin as the sheets that go to make the outside covers, other portions are so thick as to be rigid and brittle. Very often the nest is built around the branch, so that the lower combs also benefit by having a point of attachment, though this is not always the case. But whether or not they have this advantage, the lower combs are always attached to the one above by stout ridges on the roof of the comb. The amount

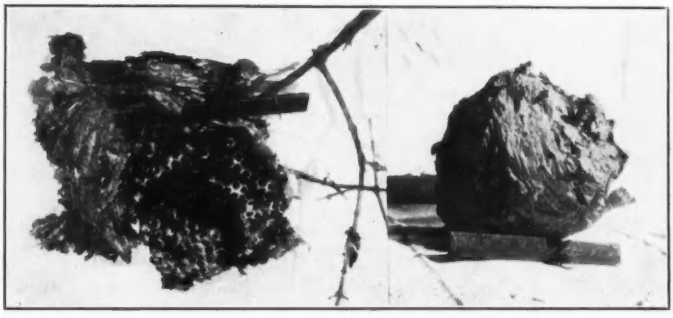

Figure 6 **Figure 7**

Fig. 6. A last year's weather-beaten nest of *Vespa maculata*.
Fig. 7. A nest of *Vespa maculata* abandoned before it had attained more than a fourth of its full size.

of such attachment varies according to whether or not they have a twig also for their support. Figure 8 shows the roof of a middle comb and these ridges which fastened it to the comb above; the irregularity of the ridges is due to the fact that the point of attachment to the comb above is always among the cells containing living organisms, and these supports follow a zigzag course so as to come between the cells, instead of blocking some poor creature's doorway. These ridges are massive, and I believe any colony would find it advantageous to build in such a way that a twig would penetrate all the combs and thus save much building of ridges.

While one expects to see these nests hanging from branches—and I have never seen a full-grown one that did not—I have

seen four or five small and abandoned ones in other situations, such as the eaves of buildings. While the one in figure 2 would probably have come to maturity if it had not been disturbed, those in the eaves were in such narrow places that full growth would have been utterly impossible, and hence they were abandoned in an early stage. I suspect further that their existence is not always a rosy one. One nest (Fig. 7) was found in the autumn, attached to a twig but abandoned when

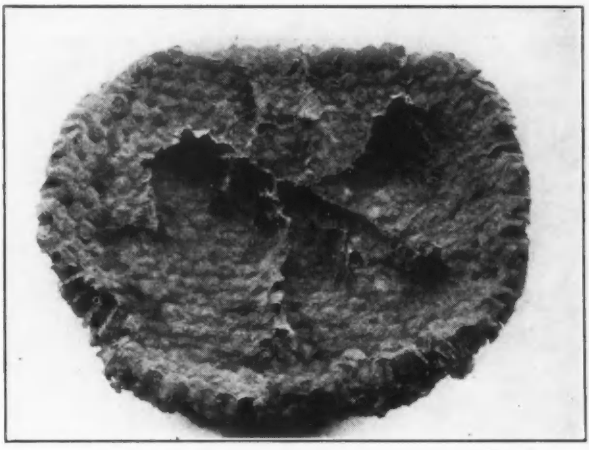

Figure 8

Fig. 8. The comb of *Vespa maculata* showing the stout ridges by which it is fastened to the comb above.

only about one-fourth full size; we can only surmise that some disaster had befallen the builders to cause them to abandon the nest, or that this group had had the same history as that recorded for the fifteen workers and a remnant of paper.

One very often reads, especially in English publications, that certain years are favorable wasp years and others are not. The writers often attribute this to the wet or dry condition of the spring, asserting that wet weather early in the season causes much mortality to the queens before the colony is safely founded. All of the observations herein recorded were made at Wickes, Mo., in 1920. I spent much of the summer of 1917 and 1918 at this place and made it my business to look

for these nests, since in all the days of my life I had never seen a hornets' nest in its natural position. In these two years, none were found, although occasionally workers were seen on the wing. In 1919 I was kept in the city, but in 1920 when I again got to Wickes, I discovered during the summer half a dozen live nests and about the same number of old nests, more or less dilapidated. In 1921, a careful search revealed no new nests, although early in the season a number of queens were seen.

Figure 9 ***Figure 10***

Fig. 9. A well concealed nest of *Vespa maculata* in an apple tree.
Fig. 10. A nest of *Vespa maculata* swinging in the tree tops.

Now I firmly believe that weather is one factor in determining the frequency of these wasps. I wish to add, however, that I believe the abundance of fruit is a very important factor which should not be left out of consideration. In England, these insects are destroyed in great numbers because of the injury they inflict on the ripening fruit. In 1919, our region enjoyed the greatest fruit crop that had occurred for several years; in 1920, the fruit crop was fair; in 1921, the frost killed everything, so that in this entire region not even a persimmon or a pawpaw could be found. This correlates nicely with the occurrence of *V. maculata*. Cold is also a factor influencing the population by shortening the duration of their lives. This point was brought to my attention by the condition of two nests observed on October 13. One was on a hillside facing northwest; this showed no activity, and when I removed it

from the tree with a long pole, only a few soft, newly-dead wasps fell out of it. Three hundred yards from this point, in an apple tree in a sheltered, sunny situation, was another nest which was filled with bustling activity on the same day. I had one of the natives keep watch for me, and he reported that for a week thereafter some bees were seen coming and going from the orchard nest. On October 13th, I noted that the workers that flew in were much smaller than the usual workers, and in size resembled those first four recorded when they emerged in June. This may have been due to the shortage of food at both extremes of the season.

The nests of *V. maculata* are often so hidden by foliage that it is a wonder that even the workers themselves can find them. Figure 3 shows a nest among the foliage, with the lights and shadows blending nicely to protect it in its mottled gray; the foliage in front of the nest was cut away during the night to expose it for photographing. Figure 9 shows a nest nicely protected among the foliage of an apple tree; it is quite large, with only a small portion visible. But why the nests should need to be protected, I cannot for the life of me see! Perhaps, however, these little fellow citizens of our planet have specialized so excessively on their defense that their defiance is a boomerang which brings back the wrath of other creatures upon them and leads to their destruction. Thus in the end these bold and formidable warriors never rise, in permanent population, above the butterflies or song birds. How immutable are Nature's laws of give and take!

AN ANNOTATED LIST OF THE TACHINIDÆ OF MISSISSIPPI.

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This list has been compiled from data on material obtained on several collecting trips in different parts of the State, and from records obtained by rearing parasites from lots of insects received from numerous locations. The work was done between 1920 and 1925, which includes two seasons of intensive study of Tachinidæ at Agricultural and Mechanical College, Mississippi. Acknowledgments are made to Dr. J. M. Aldrich, who has checked the questionable determinations of Tachinidæ and verified the names used, to Dr. J. M. Beal for determinations of plants mentioned, and to the several collectors whose names appear in the list.

The seasonal distribution of adult Tachinid population is probably parallel to the species population as presented in Figure 1. January and the colder parts of February comprise the only period in which adults were not observed. There are two well marked peaks of abundance, as is indicated by the curve for species observed in the field. One is contemporaneous with the maturing of the early spring herbaceous vegetation, and rises to an apex of 23 species listed as occurring in the middle of May; the other occurs at the beginning of the cooler, more humid weather of late summer, and rises to an apex of 50 species in late September. This is considerably greater than the spring peak. The periods of greater abundance are separated by a period during the hot and frequently very dry summer, in which few Tachinidæ can be found in the field.

Within the region studied, Tachinid adults were normally more abundant in moderately dense, succulent, herbaceous vegetation from about one foot to several feet tall, and represented by such aggregations as fields of crimson clover, vetch, cowpeas, cotton, dense weeds, the weedy fringes of woodlands, or even open woods with frequent thickets of weeds and shrubs. Favorable habitats for adults were notably more

*Submitted as a contribution from the Mississippi Agricultural Experiment Station.

widely expanded during the comparatively moist, cool days of spring and fall, but shrank, during the hot, dry summer months, to the edges of swamp forests, or lowlands having a dense protective covering of succulent vegetation. At such times adult Tachinidæ become exceedingly scarce over wide areas of short-grass pasture, grasslands, and cultivated fields, particularly on the poorer upland soils.

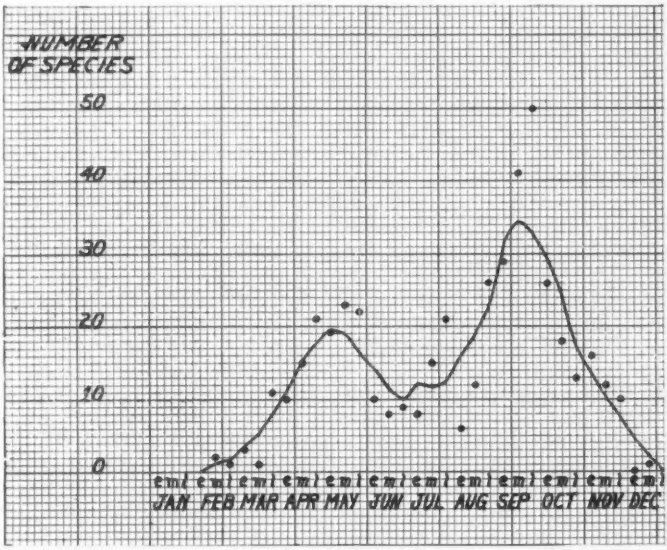

Figure 1. Curve of the distribution of Tachinidæ in Mississippi. Each small circle marks the number of species recorded as present in the adult stage during the portion of the month indicated.

By arranging the species listed into groups according to the seasons in which the adults of these species are known to occur in the state, the following information may be obtained:

Seasons in which adults are present	*Number of species present*
Spring	19
Summer	20
Fall	14
Spring and fall	14
Spring and summer	8
Summer and fall	20
Spring, summer, and fall	26
Total number of species	121

TABLE I.

THE FEEDING HABITS OF ADULT TACHINIDÆ.

SPECIES OF TACHINIDÆ UPON WHICH OBSERVATIONS WERE MADE	FLOWERS AT WHICH FEEDING WAS OBSERVED												NECTARIES AT WHICH FEEDING WAS OBSERVED			
	Spirea vanhouttei	Lepidium virginicum	Erigeron sp.	Chaerophyllum tainturieri	Anthemis cotula	Melilotus alba	Rhus glabra	Polygonum pennsylvanicum	Polygonum persicarioides	Euphorbia nutans	Bidens aristosa	Chrysanthemum	Stems of cowpea	Stems of smooth vetch	Peach leaves	Honeydew
Proboscis longer than head-height:																
Cistogaster immaculata	x	x	x		x							x				
Cistogaster occidua			x									x				
Gymnosomma fuliginosa			x		x								x			
Phasia diversa	x		x	x								x				
Phasia grandis	x															
Phasia nitida	x															
Phasia pulverea												x				
Phoranthella calyptrata	x		x									x				x
Phoranthella occidentis	x		x									x				x
Leucostoma sp.										x						
Epigrimyia polita			x													
Siphoclytia robertsoni							x									
Plagiomima anomala			x													
Bonnetia comta									x			x	x	x		
Pyraustomyia penitalis								x								
Cuphorocera furcata												x				
Copecrypta ruficauda	x	x		x		x		x	x	x						
Archylas analis	x			x		x		x			x	x		x	x	x
Proboscis as long as head-height:																
Distichona varia													x			
Atacta braziliensis									x							
Atacta crassiceps									x							
Ernestia ampelus				x												
Phorocera claripennis													x			x
Phorocera floridensis													x			x
Gonia texensis											x					
Gaediopsis flavipes									x				x			
Archylas hystrix												x	x			x
Proboscis shorter than head-height:																
Myiophasia globosa							x									
Lixophaga variabilis													x			
Tachinophyto indecisa													x			
Ervia triquetra												x	x			
Metavoria orientalis													x			
Belvosia bifasciata								x								x
Belvosia unifasciata													x			
Nemorilla floralis																x
Zenillia confinis										x			x			
Phorocera tortricis																x
Exoristoides slossonæ													x			
Doryphorophaga doryphoræ									x				x			
Achaetoneura archippivora													x			x
Achaetoneura aletiæ												x	x			
Achaetoneura frenchii													x			
Achaetoneura melalophæ															x	
Masicera senilis													x			
Sturmia distincta										x		x	x			x
Sturmia inquinita													x			
Winthemia quadripustulata										x			x		x	x
Phytoadmontia seligera													x			
Paradidyma singularis													x			
Pseudochaeta argentifrons													x			
Exorista larvarum													x			x
Totals	8	2	8	4	2	2	2	4	6	5	2	13	26	2	3	14

Further collecting would undoubtedly extend the seasonal distribution of numerous species, thus decreasing the numbers listed for one season, and increasing the number listed for two or three seasons. Although the information is incomplete, two significant points are indicated by the seasonal tabulation of species as given. First, the number of species overlapping from spring into summer was notably less than the numbers of those occurring in the spring or fall only, or overlapping from summer into fall. Second, there was a total of 47 species which were found in the spring, in the fall, or in both spring and fall, but which did not occur during the summer. These two points indicate that there is a distinct cool-season group of Tachinidæ which are not present as adults during mid-summer. This group, however, is outnumbered by the 74 species listed as being present at some time during the summer. The number occurring continuously in spring, summer, and fall slightly exceeds one-fifth of all those listed. As might be expected, this fifth includes a large proportion of species which are dominant not only in Mississippi, but in large areas of eastern North America, such as *Gymnosoma fuliginosa*, *Trichopoda pennipes*, *Myiophasia metallica*, *Lixophaga variabilis*, *Cylindromyia euchenor*, *Phorocera tortricis*, *Achaetoneura archippivora*, *Sturmia distincta*, *Winthemia quadripustulata*, *Exorista larvarum*, *Copecrypta ruficauda*, *Archytas analis*, and others.

When the seasonal distribution of species of a group including the genera *Phorocera*, *Zenillia*, *Achaetoneura*, *Sturmia*, and *Masicera*, which represent the central and dominant nucleus of the family, is compared with that of the species of a group including the Phasiinæ, *Cylindromyia*, *Beskia*, *Xanthomelana*, and *Hemyda*, which are sluggish, bizarre forms, widely different from the central nucleus, some interesting information is obtained. Of the species listed as not occurring during the summer, 11 are of the second group and only 4 are of the first, while of the species listed as occurring in the summer, 21 are of the first group and only 9 are of the second. This suggests for the Phasiinæ and allied sluggish, bizarre forms, a tendency toward segregation in the cooler, moister portions of the growing season, and the domination of the hot, dry, mid-summer period by the more active, generalized, central nucleus of the family.

The food habits of the adult Tachinidæ were noted wherever observed, and are recorded in Table I. There are, roughly

classified, three common sources of food for the adults, flowers, nectaries on stems and leaves, and honeydew. All the flowers that are known to be visited by two or more species of Tachinidæ have been listed in the approximate order in which they bloom. Two common ornamental plants, the hardy chrysanthemum, which blooms in the fall, and *Spirea vanhouttei*, which blooms in the spring, are both visited by many species of Tachinidæ. Certain species of wild flowers, such as *Erigeron*, *Polygonum persicarioides*, and *Euphorbia nutans* are frequented by several Tachinidæ. On the other hand, a number of species, although blooming in great profusion over the region studied, attract Tachinidæ only occasionally or not at all. *Helenum tenuifolium* belongs to this group. Tachinidæ also feed at the nectaries that occur on the stems or leaves of certain plants, such as those at the bases of peach leaves, on the stems of smooth vetch, and on the fruiting stems of cowpeas. The nectaries of cowpeas attract Tachinidæ in vast numbers at the peak of their abundance in late summer, 28 different species having been observed feeding there and as many as 15 species simultaneously in the same field. Certain aphids and scale insects also, which produce a copious flow of honeydew, are attended by large numbers of Tachinidæ.

Tachinidæ may be divided roughly into two classes on the basis of the food habits of the adult. The first includes those species which habitually visit flowers, and the second includes those which feed at non-floral nectaries or on deposits of honeydew. The difference of habit is associated with a difference in the structure of the proboscis. The habitual flower feeder has a slender, strongly-chitinized, elongate proboscis with a small labella at the tip, well adapted for reaching deeply seated secretions of nectar in flowers. The honeydew and surface-nectary feeder, on the other hand, has a short, stout, more flexible proboscis with a large, fleshy labella, better adapted to feeding from exposed surfaces, but very poorly adapted to sucking nectar from flowers, except in species in which the floral nectaries are poorly protected. The species in Table I have been grouped to indicate the relationship between structure of proboscis and feeding habit. Of the 18 species in which the proboscis is longer than the vertical diameter of the head, 13 have been taken at flowers only, 5 at flowers and also at surface nectaries or honeydew, but none at surface nectaries or honey-

dew or both, exclusively. Of the 22 species in which the proboscis is shorter than the vertical diameter of the head, 1 was found feeding at flowers only, 7 at surface nectaries or on honeydew deposits and also at flowers, and 16 at surface nectaries and honeydew deposits only. Of the 9 species in which the proboscis is about as long as the vertical diameter of the head, and in which the adaptation to flower-feeding occurs, though it is not as pronounced as in the first group of 18, 3 were found at surface nectaries or honeydew only, 4 at flowers only, and 2 both from flowers and from surface nectaries or honeydew.

Actual dates of collecting are omitted in the following list, but the month is considered to consist of three nearly equal portions, namely, early (e), middle (m), and late (l). Unless otherwise noted collections were made by the writer, and, unless other localities are specified, all notes refer to Agricultural & Mechanical College. Citations to literature are given thus: (3–20). The numbers in heavy type indicate the total numbers of determined specimens from Mississippi localities, and serve as rough approximations of the comparative abundance of the species.

Cistogaster immaculata Macquart.
Distribution: Tupelo, l. Sept.; A. & M. College, e. Mar., m. Apr. (F. M. Hull), l. Apr., **1.** May; Starkville, e. June; **13.** *Feeding habits:* attracted to several flowers but most abundant at the flowers of *Erigeron*.

Cistogaster occidua (Walker).
Distribution: Tupelo, l. Sept.; A. & M. College, e. Apr., m. and l. May, m. Oct.; **10.**. *Feeding habits:* similar to the preceding species.

Gymnosoma fuliginosa R. Desvoidy.
Distribution: New Albany, l. Sept.; Tupelo, l. Sept.; West Point, m. May; A. & M. College, (8–43), m. May, l. May (M. R. Smith) (F. M. Hull), l. July (F. M. Hull); **11.**

Phasia aenoventris (Williston).
Distribution: A. & M. College, l. Mar., m. May; **2.**

Phasia diversa (Coquillett).
Distribution: A. & M. College, l. Mar. to m. Apr. (F. M. Hull) (B. A. Dixon) (Allen), e. and m. Nov.; **22.** Common in the spring and fall, but none have been collected from the middle of April to November.

Phasia grandis (Coquillett).
Distribution: A. & M. College, l. Mar. (F. H. Jones) (Allen), e. Apr.; **6.**

Phasia nitida (Coquillett).
Distribution: A. & M. College, l. Mar.; **1.**

Phasia pulverea (Coquillett).
Distribution: A. & M. College, m. Nov.; **1.**

Phoranthella calypterata (Coquillett).

Distribution: A. & M. College, e. and l. Apr., e. May (A. McIntosh), m. May, throughout Nov.; **28.** No females have been taken, and no adults have been observed from late May until November. *Feeding habits:* most common at *Erigeron* in the spring, and at Chrysanthemum in the fall. One of the few long-tongued nectar-sucking species that has been observed feeding on honeydew deposits in considerable numbers.

Phoranthella occidentis (Walker).

Distribution: New Albany, l. Sept.; A. & M. College, l. Mar., l. Apr. (E. W. Stafford) (Allen), e. and l. May, m. and l. Nov.; **9.** Females far outnumbered the males, and occurred in mixture with males of *calypterata*. *Feeding habits:* the same as the preceding species.

Phoranthella purpurescens Townsend.

Distribution: A. & M. College, l. Apr., e. May; **2.**

Trichoroda lanipes (Fabricius).

Distribution: A. & M. College, e. May, m. July; **3.**

Trichoroda pennipes (Fabricius).

Distribution: Tupelo, l. Sept.; A. & M. College, e. May, m. June (J. W. Bailey), m. Aug., e. Sept.; Sellars, m. Sept.; Mississippi, (8-48); **34.** *Habits:* adults have been observed in abundance about summer squashes heavily infested with squash-bugs, during the late afternoon, but were not active in the same locations during the intense light and heat of midday. *Hosts:* occasionally abundant as a parasite of the squash-bug (*Anasa tristis*) and of the leaf-footed bug (*Leptoglossus phyllopus*).

Myiophasia flohosa (Townsend).

Distribution: New Albany, l. Sept.; Tupelo, l. Sept.; A. & M. College, l. May, m. and l. Sept., e. and m. Oct.; **15.** Moderately abundant from 1920 to 1922, but scarce during the three following years. *Hosts:* potato stalk borer (*Trichobaris trinotata* Say) in the seed pods of Jimson weed. Several flies of this species also emerged from cotton bolls infested with the boll weevil (*Anthonomus grandis*), from which probably they had emerged.

Myiophasia metallica (Townsend).

Distribution: Tupelo, l. Sept.; A. & M. College, m. Apr. (A. McIntosh), e. May, e. Sept., e. and m. Oct.; West Point, m. May; Sessums, e. Aug.; Crawford, e. Aug.; Ocean Springs, e. Sept.; **16.**. Abundant in rank herbaceous vegetation during 1920 to 1922, but scarce the next three seasons.

Myiophasia nigrifrons (Townsend).

Distribution: Holly Springs, l. Sept.; **1.**

Emphanopteryx risca (Walker).

Distribution: A. & M. College, e. Apr. (F. M. Hull); **1.**

Lispidea palriger Coquillett.

Distribution: A. & M. College, m. Apr., l. July; **2.**

Thryptocera americana Townsend.

Distribution: A. & M. College, l. July, l. Sept.; **2.** *Habits:* trapped at high window, as if while migrating.

Chaetopl lers setosa Coquillett.

Distribution: Holly Springs, l. Sept.; A. & M. College, l. Mar., e. May; **5.** *Habits:* this little fly was abundant in an infestation of the striped cucumber-beetle (*Diabrotica vittata* Fabr.), in early May, 1922, where it was observed attacking adult beetles. The flies which were mostly females, were found to remain on the melon foliage near the host throughout the night as well as during the day.

Chaetostigmopte a crassinervis (Walton).

Distribution: A. & M. College, e. May; **1.**

Chaetophlepsis tarsalis Townsend.
Distribution: A. & M. College, m. Apr., l. Aug., e. Oct.; **3.** *Hosts: Autographa oo* Cram. on cowpea.

Celatoria diabroticæ (Shimer).
Distribution: A. & M. College, m. and l. Apr., m. (S. Robinson) and l. May, l. July, l. Aug., e. and m. Sept.; Meridian, e. Sept.; **15.** Adults present from early spring to fall, but rarely in abundance. *Habits and hosts:* most frequently encountered on the foliage of bean, potato, and similar crops infested with their hosts, the spotted cucumber-beetle (*Diabrotica duodecempunctata* Fabr.) and the bean leaf-beetle (*Ceratoma trifurcata* Forst.).

Admontia pergandii Coquillett.
Distribution: A. & M. College, (8–54), l. Nov. (H. W. Chalkley); **3.**

Aubaeanetia assimilis Townsend.
Distribution: A. & M. College, m. July; **1.**

Lixophaga variabilis (Coquillett).
Distribution: Doddsville, l. July; Scott, l. July; Rome, l. July; A. & M. College, e. and m. May, l. June, throughout July, l. Aug., e. Sept., e. Oct.; **21.** *Hosts:* reared from *Epiblana strenuana* Wlk., a small lepidopterous borer in the stems of ragweed, at A. & M. College, and in 1924, from several lots of garden webworm (*Loxostege similalis* Guen) collected at different localities in the Yazoo Delta section.

Oedematocera gilvipes (Coquillett).
Distribution: A. & M. College, l. Apr., e. May, m. July, l. Aug., m. and l. Sept., m. Oct.; Ocean Springs, e. Sept.; **25.** *Habits:* not generally abundant, but in the late summer of 1922, a considerable number were noted on screened porches, and the windows of college buildings up to 40 feet or more from the ground, and were presumably trapped at such places while migrating.

Tachinophyto indecisa (Townsend).
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Grenada, m. Sept.; Starkville, m. Sept.; A. & M. College, e. Sept., m. Sept. (E. W. Stafford), e. Oct.; Moss Point, e. Sept.; **27.** Encountered in abundance at Moss Point on luxuriant weeds of a neglected garden.

Arrhinomyia barbarta (Coquillett).
Distribution: A. & M. College, l. Apr.; **1.** On crimson clover.

Paralispe barbarta (Bigot).
Distribution: A. & M. College, l. Oct.; **1.** *Feeding habits:* taken at the nectaries of cowpea.

Paralispe infernalis Townsend.
Distribution: A. & M. College, l. Oct. (G. M. Williams); **1.** *Feeding habits:* taken at the nectaries of cowpeas.

Xanthocera clistoides Townsend.
Distribution: A. & M. College, m. Oct.; **1.**

Ervia triquetra (Olivier).
Distribution: A. & M. College, (8–66), e. May (S. Robinson), m. and l. May, m. June (C. C. Greer), e. and l. Aug., throughout Sept., e. and m. Oct., l. Oct. (H. Gladney), e. and m. Nov. (H. Gladney); Mulden, e. June (H. L. Dozier); West Point, m. May; **33.** *Habits:* adults moderately abundant, and occurring in a wide range of habitat. Aside from frequenting the food sources listed in Table I, they have been observed in tall-grass meadows, on young corn, and on the foliage of pecan.

Leskiomima tenera (Wiedemann).
Distribution: Wiggins, (C. E. Pratt); **1.** *Host:* our only specimen was obtained from a breeding cage stocked with pecan case-bearers (*Mineola indiginella nebulella* Riley) from south Mississippi, under circumstances somewhat doubtfully indicating this host relationship.

Leucostoma acuminata Townsend.
Distribution: A. & M. College, e. Oct., m. Nov.; **6.** *Hosts:* adults were observed making attacks on *Corizus hyalinus* (Fabr.) heavily infesting a garden weed, *Euphorbia nutans*. *L. acuminata* was subsequently reared from this host.

Leucostoma sp.
Distribution: New Albany, l. Sept.; Tupelo, l. Sept.; Starkville, e. June; A. & M. College, l. May; **5.**

Hyalomyodes triangulifera (Loew).
Distribution: A. & M. College, l. May; **1.**

Ormia montana Townsend.
Distribution: A. & M. College, m. May, Sept.; Hattiesburg, m. Oct. (J. W. Champlain); **3.**

Cenosoma signifera Van der Wulp.
Distribution: A. & M. College, l. Mar. (E. W. Stafford), m. June (A. McIntosh); **2.**

Hemyda aurata R. Desvoidy.
Distribution: Greenville, m. Sept.; A. & M. College, m. May; Meridian, e. Sept.; **2.**

Xanthomelana attripennis Say.
Distribution: Tupelo, l. Sept.; Rosedale, m. Sept.; A. & M. College, Sept.; **4.**

Beskia aelops (Walker).
Distribution: Starkville, e. June; A. & M. College, l. May, m. Sept.; Ocean Springs, e. Sept.; **4.** *Habits:* This brilliantly-marked little fly is occasionally encountered in the spring and fall, in luxuriant weeds and grass in comparatively moist locations. It is noticeably slow and feeble in flight.

Epigrimyia floridensis (Townsend).
Distribution: A. & M. College, l. Apr., l. May; **2.**

Epigrimyia geniculata (Townsend).
Distribution: A. & M. College, early spring; **3.** *Habits.* Reared from undetermined Pyralid or Tortricid larvæ hibernating in a colony under the bark of a dead tree. Emergence was very early, occurring between February 12 and early March.

Epigrimyia polita Townsend.
Distribution: A. & M. College, throughout May; West Point, m. May; **7.**

Siphoclytia robertsoni Townsend.
Distribution: A. & M. College, l. May; **1.**

Plagiprospherysa parvipalpis (Van der Wulp).
Distribution: Gulfport, e. Sept.; **1.** *Habits:* taken on sandy marine beach.

Blepharigena spinulosa (Bigot).
Distribution: A. & M. College, m. May (S. Robinson); **1.** *Hosts:* the army worm (*Cirphis unipuncta* Haw.).

Metavoria orientalis Townsend.
Distribution: A. & M. College, l. Apr., throughout May, l. June, m. July, l. Oct.; Moss Point, e. Sept.; **534.** *Habits:* adults were found moderately abundant on potato foliage infested with the host. *Hosts:* the tomato worm, (*Protoparce sexta* Johan).

Voria ruralis (Meigen).
Distribution: Holly Springs, l. Sept.; A. & M. College, l. Aug.; **2.**

Plagiomima anomala (Townsend).
Distribution: A. & M. College, m. Apr., e. Oct.; **2.** *Feeding habits:* Observed feeding at the flowers of a wild aster (*Aster exilis*) and of *Erigeron*.

Pseudotractocera lacnosternæ (Townsend).
Distribution: A. & M. College, e. June (H. M. Harris); **1.**

Pseudotractocera mutabilis (Coquillett).
Distribution: A. & M. College, m. July; **1.**

Pseudotractocera neomexicana Townsend.
Distribution: A. & M. College, e. June (H. M. Harris); **1.**

Distichona varia Van der Wulp.
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Starkville, e. May (J. M. Langston), e. June, l. Sept.; A. & M. College, (8–79), l. Apr., e. and l. May, l. Aug., throughout Sept., e. Nov.; **31.** *Habits:* Adults usually present from early spring until late fall, though not in large numbers. It is most abundant in the fall, feeding at the nectaries of cowpeas.

Atacta braziliensis Schiner.
Distribution: A. & M. College, e. Oct.; Bay Saint Louis, m. Sept.; **2.**

Attacta crassiceps Aldrich.
Distribution: Tupelo, l. Sept., (2–31); A. & M. College, e. Oct.; **2.**

Siphosturmia rostrata (Coquillett).
Distribution: McHenry, m. Sept.; **1.**

Belvosia bifasciata (Fabricius).
Distribution: Grenada, m. Sept.; A. & M. College, (4–31); McHenry, (4–31), e. Sept.; Mississippi, (8–84); **6.** *Feeding habits:* in addition to its visits to several species of flowers, it has been observed feeding on the honeydew of the tulip-tree soft-scale (*Toumeyella liriodendri* Gmel.) in tree-tops 20 or more feet from the ground.

Belvosia borealis Aldrich.
Distribution: A. & M. College, (4–29).

Belvosia semiflava Aldrich.
Distribution: A. & M. College, (4–11).

Belvosia unifasciata (R-Desvoidy).
Distribution: New Albany, l. Sept.; Tupelo, l. Sept.; A. & M. College, l. Mar., e. and m. Apr., l. Sept., and e. Oct.; West York, (4–21); Mississippi, (8–84); **14.** *Habits:* Adults were fairly common in the spring in fields of vetch, and in the fall at the weedy edges of swamp woods or over Johnson-grass meadows.

Cylindromyia dosiades (Walker).
Distribution: Tupelo, l. Sept.; Starkville, e. June; **2.**

Cylindromyia euchenor (Walker).
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Starkville, e. Apr.; A. & M. College, m. Apr., l. May, l. Aug.; **9.**

Cylindromyia nana (Townsend).
Distribution: McHenry, m. Sept.; **1.**

Cylindromyia vulgaris Aldrich.
Distribution: A. & M. College, l. Aug.; **1.**

Bonnetia comta (Fallen).
Distribution: Grenada, m. Sept.; Tupelo, l. Sept.; A. & M. College, m. and l. Apr., m. May, Sept., e. Oct., e. and m. Nov.; **6.**

Pyraustomyia penitalis (Coquillett).
Distribution: A. & M. College, throughout August, numerous reared specimens; maggots of this species were noted within the host larvæ at Hernando, Holly Springs, Tupelo, Grenada. *Hosts:* A common species of the smartweed borer (*Pyrausta ainsliei* Hein.).

Ernestia ampelus (Walker).
Distribution: A. & M. College, l. Apr., m. Sept. (J. L. Williams); **2.** *Hosts:* the fall webworm (*Hyphantria cunea* Dru.).

Nemorilla floralis Fallen.

Distribution: Holly Springs, l. Sept.; Grenada, m. Sept.; A. & M. College, e. and l. July, m. Sept., throughout Oct., m. Nov.; Ocean Springs, e. Sept.; Moss Point, e. Sept.; **9**. *Feeding habits:* Observed feeding on honeydew in separate infestations of aphids on corn, melons, and turnips, also seen on cowpeas, though not in the act of feeding. *Hosts:* Reared from the grape leaf-folder (*Desmia funeralis* Hueb.), over an infestation of which the adults were observed active, and from a bud worm of dahlia, *Pyrausta tyralis* Guen.

Zenillia amplexa Coquillett.

Distribution: A. & M. College, m. Oct.; Artesia, l. Aug.; Meridian, m. Oct.; Pascagoula; Mississippi, (8–100); **1** collected, several reared. *Hosts:* Reared from cocoons of the stinging caterpiller (*Megalopyge opercularis* S. & A.) received from several parts of the state.

Zenillia blanda blanda (Osten Sacken).

Distribution: Holly Springs, l. Sept.; Adaton, m. Aug.; A. & M. College, l. July, m. and l. Aug., m. Sept.; Mississippi, (1–39); **8.** *Habits:* Although not common in the field, several adults have been trapped on screened porches or at high windows as if in migration. They have been observed on cowpeas. *Hosts:* the canna leaf-roller (*Calpodes ethlius* Cram.).

Zenillia caesar (Aldrich).

Distribution: A. & M. College, l. July; **1.**

Zenillia confinis (Fallen).

Distribution: Walls, l. July (T. E. Saunders); Holly Springs, l. Sept.; Tupelo, l. Sept.; A. & M. College, Mar., l. June, e. Oct., e. Nov.; **8.** *Hosts:* the cotton square-borer (*Uranotes melinus* Hueb.).

Zenillia eudryæ (Townsend).

Distribution: Greenville, m. Sept.; **1.**

Zenillia reclinata Aldrich and Webber.

Distribution: A. & M. College, m. Nov.; **1.**

Zenillia setinervis (Coquillett).

Distribution: Meridian, e. Sept.; **1.** Taken on cowpeas.

Phorocera claripennis (Macquart).

Distribution: Holly Springs, l. Sept.; A. & M. College, m. May, m. Sept., e. Oct. (H. M. Harris), m. and l. Oct., e. Nov.; Woodland, l. June; Meridian, l. Aug. (M. L. Grimes); Ocean Springs, e. Sept.; Bay Saint Louis, m. Sept.; Mississippi, (8–102); **25.** *Feeding habits:* Adults feed on the honeydew secreted by the corn aphid (*Aphis maidis* Fitch). *Hosts:* the red-humped caterpillar (*Schizura concinna* S. & A.), the yellow-necked caterpillar (*Datana ministra* Dru.), the poplar tent-maker (*Melalopha inclusa* Hueb.), the silver-spotted skipper (*Epargyreus tityrus* Fabr.), and *Apantesis oithona* Str.

Phorocera floridensis Townsend.

Distribution: Beuna Vista, l. June (S. T. Wing); A. & M. College, m. and l. June, l. July, m. Aug., throughout Sept., and Oct., e. and l. Nov.; West Point, l. Sept.; Greenwood; **30.** *Feeding habits:* Adults feed on the honeydew secreted by the turnip aphid (*Rhopalosiphum pseudobrassicæ* Davis), and are frequently present in the field in association with those of the preceding species. *Hosts: Datana ministra, Melalopha inclusa, Epargyreus tityrus, Apantesis oithona* and *Autographa oo* Cram.

Phorocera leucaniæ Coquillett.

Distribution: A. & M. College, m. and l. May, e. June, e. Oct.; **5.** *Habits:* Adults were observed several times in early summer on hairy vetch and other luxuriant vegetation. *Hosts:* reared in early October from the cotton army worm (*Alabama argillicæ*).

Phorocera noctuiformis Smith.
Distribution: A. & M. College, l. July, l. Sept.; **3.** *Habits:* Taken from cowpea and trapped at window, 40 feet above the ground.

Phorocera parviteres Aldrich and Webber.
Distribution: A. & M. College, l. July, l. Aug.; Moss Point, e. Sept.; **4.** *Habits:* Adults were captured from cowpeas, also from windows 40 feet above the ground, where they had evidently been trapped while migrating.

Phorocera signata Aldrich and Webber.
Distribution: A. & M. College, e. Sept. (C. E. Wilson); **1.**

Phorocera sulcata Aldrich and Webber.
Distribution: A. & M. College, l. Aug.; **1.** Taken from cowpeas.

Phorocera tortricis Coquillett.
Distribution: Grenada, m. Sept.; Starkville, m. Aug.; A. & M. College, m. May, m. and l. July, e. Aug., m. and l. Sept., e. Oct., e. Nov.; Crawford, m. Aug.; Sellars, m. Sept.; Bay Saint Louis, m. Sept.; **30.** *Feeding habits:* Females frequently found feeding at the nectaries of cowpeas, and on one occasion on the honeydew of the corn aphis (*Aphis maidis* Fitch).

Pelecotheca panamensis Townsend.
Distribution: A. & M. College, l. Aug., m. Sept.; Utica, (8–103); **3.**

Exoristoides slossonæ Coquillett.
Distribution: Holly Springs, e. Sept.; Grenada, m. Sept.; Grenada, m. Sept.; A. & M. College, e. Sept.; **4.**

Doryphorophaga doryphoræ (Riley).
Distribution: m. (C. N. Yelverton) and l. Aug., m. and l. Sept., e. Oct.; Meridian, e. Sept.; Moss Point, e. Sept.; **8.** *Hosts:* Adults moderately abundant in the fall on the foliage of potatoes infested with the Colorado potato beetle (*Leptinotarsa decemlineata* Say) from which it was reared occasionally.

Xiphomyia texana Reinhard.
Distribution: Holly Springs, l. Sept.; Tupeto, l. Sept.; **2.**

Achaetoneura archippivora (Williston).
Distribution: Tupelo, l. Sept.; Holly Springs, l. Sept.; Starkville, m. Aug.; A. & M. College, m. June, m. Aug., throughout Sept.; Ocean Springs, e. Sept.; Moss Point, e. Sept.; **46.** *Habits:* Moderately abundant in late summer and early fall, when it was frequently taken at the nectaries of cowpeas, less often on mung beans and feeding on the honeydew of *Aphis gossypii* Glov., on cotton.

Achaetoneura aletiæ (Riley).
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Adaton, l. July; A. & M. College, m. and l. May, l. July, l. Aug., m. and l. Sept., e. and m. Oct., throughout Nov.; Sellars, m. Sept.; Bay Saint Louis, m. Sept.; Gulfport, e. Oct.; Pascagoula, l. May; Moss Point, e. Sept.; Mississippi, (8–107); **75.** *Hosts and habits:* (7–188).

Achaetoneura frenchii (Williston).
Distribution: Holly Springs, l. Sept.; A. & M. College, m. Sept., l. Oct. (G. R. Williams), e. Nov.; **9.** Not nearly as abundant as *A. aletiæ*. *Hosts:* Overwinters in the cocoons of the polyphemus moth (*Telea polyphemus* Cram.).

Achaetoneura melalophæ Allen.
Distribution: A. & M. College, (7–192), m. and l. Feb., throughout Mar., m. and l. Apr., throughout July, e. and m. Sept., m. Oct.; **51.** *Hosts and habits:* (7–192).

Frontina rileyi (Williston).
Distribution: Gulfport, e. June (Harmon); **1.** *Hosts:* the orange dog (*Papilio thoas* L.) in south Mississippi.

Lydella eufitchiæ (Townsend).
Distribution: A. & M. College, m. May (F. M. Hull); **1.**

Masicera senilis (Meigen).
Distribution: A. & M. College, e. Nov.; **3.**

Sturmia albifrons (Walker).
Distribution: Tupelo, l. Sept.; A. & M. College, m. July, (F. M. Hull), l. Aug.; **3.**

Sturmia distincta (Wiedemann).
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; A. & M. College, l. Apr., e. and m. May, m. and l. July, e. and l. Aug., m. and l. Sept., throughout Oct., e. and m. Nov.; Meridian, e. Sept.; Ripley, l. Aug. (H. E. Wallace), e. Oct.; Sellars, e. Sept.; Ocean Springs, e. Sept.; Moss Point, e. Sept.; Mississippi, (8–111); **40** collected, many others reared. *Habits:* Adults very abundant in late summer and fall on the nectaries of cowpeas. It occurs in the field, even in mid-day sunlight, at temperatures up to 84° F. and over dry soil at humidities as low as 20 per cent. *Hosts:* An important parasite of tomato worm (*Protoparce sexta*) larvæ in the late summer. A brood of late-fall emerging adults appear after this host has disappeared from the field.

Sturmia inquinita (Van der Wulp).
Distribution: Tupelo, l. Sept.; A. & M. College, e. and l. Sept., l. Oct.; Bay Saint Louis, m. Sept.; Mississippi, (8–111); **7.**

Sturmia limita Coquillett.
Distribution: Tupelo, l. Sept.; A. & M. College, l. Apr.; **3.** Males have been collected from hairy vetch in bloom.

Sturmia occidentalis Coquillett.
Distribution: A. & M. College, e. Apr.; **1.**

Sturmia phycoides Coquillett.
Distribution: New Albany, l. Sept.; Tupelo, l. Sept.; **2.**

Winthemia quadripustulata (Fabricius)
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Lamont, l. May, (J. L. E. Lauderdale); A. & M. College, l. Mar. (S. Robinson), e. and m. Apr., e. May (F. M. Hull), l. May, m. and l. July, e. and m. Aug., m. and l. Sept., l. Oct. (F. M. Hull), e. Nov.; Starkville, m. Aug.; Crawford, m. Aug.; Sellars, m. Sept.; several hundred specimens determined. *Hosts:* (5–10). *Feeding habits:* (5–20). One of the commonest Tachinid parasites. Adults are abundant from the middle of April to the middle of October, in a great variety of habitats.

Phytoadmontia setigera (Coquillett).
Distribution: Tupelo, l. Sept.; A. & M. College, m. May, l. Sept., e. and m. Oct.; **21.** Adults occasionally abundant in the fall.

Paradidyma singularis (Townsend).
Distribution: Holly Springs, l. Sept.; New Albany, l. Sept.; Tupelo, l. Sept.; A. & M. College, (8–126), l. Apr., l. Aug.; **16.** *Feeding habits:* In late September, 1921, large numbers of adults were observed feeding at the nectaries of cowpeas and on the juices of ripe persimmons which had dropped from the tree.

Acemyia dentata Coquillett.
Distribution: Tupelo, l. Sept.; Bolivar County, (10–25); A. & M. College, (8–116), l. May, l. Aug., m. and l. Sept., m. Oct.; **11.**

Pseudochaeta argentifrons Coquillett.
Distribution: Tupelo, l. Sept.; Ratliff, m. Sept.; A. & M. College, e. and l. July, l. Aug., m. and l. Sept., e. Nov.; **67.** *Habits:* Adults are frequently abundant between early July and middle September, persisting until early November. They have been encountered in large numbers feeding

from the nectaries of cowpeas. During three of the six seasons, 1920–1925, they have, at some time during the summer, been trapped by hundreds at the upper windows of college buildings, about 40 feet from the ground. During the same intervals, very few were trapped at the lower windows in the same buildings. Both sexes were present in about equal proportions among the trapped specimens. A few other species, but by no means all that were known to occur in the immediate vicinity, contemporaneously, were trapped with *argentifrons*, but in smaller numbers. Other species were taken at these windows, which were never found on the vegetation of the vicinity. The circumstances under which these flies were captured makes it seem probable that they were migrating at a considerable elevation from the ground.

Prospherysa aemulans Van der Wulp.
Distribution: A. & M. College, m. Sept.; **1.** Taken from cowpeas.

Vanderwulpia sequens Townsend.
Distribution: A. & M. College, l. July; **1.** Trapped at window about 40 feet from ground.

Houghia setipennis Coquillett.
Distribution: A. & M. College, m. Sept.; **1.**

Exorista larvarum (Linné).
Distribution: Woodland, l. June; A. & M. College, m. May, l. June, l. July, e. and l. Nov.; Macon, m. June (J. V. Pace); **17.** *Hosts:* the salt-marsh caterpillar (*Estigeme acraea* Dru.), and an Arctiid (*Apantesis oithona*) feeding on cotton.

Exorista simulans (Meigen).
Distribution: A. & M. College, l. Oct.; West Point, m. May; **2.**

Wagneria sp.
Distribution: A. & M. College, m. Dec.; **3.** *Hosts: Epsilia fungorum* G. & R.

Gonia sagax Williston.
Distribution: Starkville, l. Apr. (J. M. Falkner); **2.** From the cocoon of an undetermined Arctiid.

Gonia senilis Williston.
Distribution: A. & M. College, l. June, l. July, e. Aug.; **5.**

Gonia texensis Reinhard.
Distribution: A. & M. College, m. Aug., e. Sept. (H. Gladney and Allen); **12.** *Habits:* adults were moderately abundant in the late summer of 1924 at the flowers of *Bidens aristosa*, the nectaries of cowpeas, and hovering over tall-grass meadows.

Gaediopsis flavipes Coquillett.
Distribution: A. & M. College, l. Apr., m. July, throughout Sept.; e. Oct.; **11.** *Habits:* Adults common but rarely abundant, have been observed on the foliage of mung beans and crimson clover, and several times, feeding at the nectaries of cowpeas.

Spallanzania hesperidarum Williston.
Distribution: A. & M. College, m. Apr., Nov.; **2.**

Cuphorocera furcata (Van der Wulp).
Distribution: A. & M. College, e. Nov.; **1.**

Copecrypta ruficauda (Van der Wulp).
Distribution: Lakeview, e. Oct. (R. W. Harned); Holly Springs, l. Sept.; Greenville, m. Sept. (F. M. Hull); Grenada, m. Sept.; Tupelo, l. Sept.; Starkville, m. Aug.; A. & M. College, m. and l. Apr., l. May, e. July (F. M. Hull), l. Aug., m. Sept., l. Nov.; Columbus, m. July (F. M. Hull); Utica, (8–139); **44.** *Habits:* A common species, the adults of which frequently occur in great abundance feeding at the flowers of a number of common plants or active over dense herbaceous vegetation.

Archytas analis (Fabricius).
Distribution: Holly Springs, l. Sept.; New Albany, l. Sept.; Tupelo, l. Sept.; Grenada, m. Sept.; Weilermann, l. May; A. & M. College, l. Mar., e. and m. Apr., throughout June and July, m. Aug., m. Oct., l. Nov.; Leakesville, m. Aug.; Moss Point, e. Sept.; Bay Saint Louis, m. Sept.; **308.** *Feeding habits:* (6–425). *Hosts:* (6–432).

Archytas aterrima (R-Desvoidy).
Distribution: Holly Springs, (8–143); Tupelo, l. Sept.; A. & M. College, m. July; Purvis; **8.**

Archytas hystrix (Fabricius).
Distribution: Holly Springs, (8–142); A. & M. College, l. June (J. R. Furr), l. Aug., e. and l. Nov.; Charleston, l. Aug.; **8.**

Microphthalma disjuncta (Wiedemann).
Distribution: A. & M. College, l. Apr., e. May, e. Sept.; Utica, (8–138) (3–4); Mississippi, (9–18); **10.** *Habits:* Adults were observed on tall grass in moderate numbers early in the spring of 1921.

Spathidexia dunningi (Coquillett).
Distribution: Holly Springs, l. Sept.; Tupelo, l. Sept.; Longview; A. & M. College, m. Apr., e. May, l. July, l. Aug., m. Sept., e. and m. Oct.; Ocean Springs, e. Sept.; **27.** *Habits:* Adults, which are frequently abundant, have been swept from grass and trapped at third-story windows of college buildings and on screened porches.

Melanophora roralis (Linné).
Distribution: A. & M. College, l. Nov. (H. W. Chalkley); **2.**

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A PRELIMINARY STUDY OF LARVAL STRUCTURE IN THE DRYOPIDÆ.

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I. INTRODUCTION.

(a) *Plan and scope of the work.*

Originally undertaken with a view to making a substantial contribution to our knowledge of the biology of this group, the present work is manifestly incomplete. Circumstances prevent further investigation in the immediate future however, and it is felt that the results which have been secured are such as to warrant publication at this time. The nature of the work may be briefly explained:

All larval material available in this family has been separated into a number of distinct types, which are described herewith in detail and are accompanied with figures showing all the important distinguishing structures. The possible identity of these types, in most cases, can be only inferred by reason of their association with adult forms already known, but since no attempt has been made to establish the identity of these forms beyond the genus, such inferred identifications answer quite satisfactorily the purposes of this paper. These various larval types are then discussed with reference to the adaptation of their form and structure to the environments in which they are found, and there is included an attempt at interpretation from a phylogenetic point of view. To make more clear the distinguishing characters, also to provide for ready detection by other workers of any types not here treated, a brief analytical table is appended.

The writer is of course aware that modern views associate the Heteroceridæ and Georyssidæ with the Psephenidæ, Dryopidæ and Elmidæ in the superfamily Dryopoidea, as set forth in Leng's Catalogue ('20). In the present paper, however, the family name Dryopidæ is used in its older sense, as inclusive of the three subfamilies—Psepheninæ, Dryopinæ and Elminæ. (Cf. Parnidæ of Blatchley's Catalogue, also of Zaitzev ('08, '10).

(b) *Sources of material; acknowledgments.*

All material used in the present study was taken within the boundaries of the United States. A major portion was collected by the writer in the vicinity of Ithaca, N. Y., but a considerable quantity of western material was furnished by Dr. J. G. Needham, to whom the writer desires to make acknowledgment for much helpful encouragement and advice. Thanks are also due to Dr. W. T. M. Forbes, to Dr. G. C. Embody and to Professor W. A. Clemens for various courtesies extended during the course of the work, likewise to Dr. Adam G. Boving, for the privilege of studying the unpublished manuscript of his paper "On the Classification of Beetles According to Larval Characters."*

II. Previous Studies.

Although a very large number of titles have to do with Dryopid Coleoptera from a *taxonomic* point of view, those papers dealing with the *biology* of the group are much less numerous, and are, for the most part, widely scattered. Hence the literature as a whole affords but scant assistance in the study of larval characters. The works of certain authors, however, have proven of considerable value and should be mentioned at this point.

Müller (1806) is apparently the first to take special note of the immature stages of these forms. He is followed by other European writers, notably Westwood ('39) and Erichson ('41, '48) who record various general facts concerning both structure and behavior. DeKay ('44) makes the unhappy blunder of describing the larva of *Psephenus lecontei* Lec. as a new species of Crustacean (*Fluvicola herricki*), the identity of which is finally set right by Le Conte ('49, '50), whose correspondence with T. W. Harris (published 1869) likewise furnishes certain interesting and valuable information. Dufour ('62), Perez ('63), Laboulbene ('70), Rolph ('74), Friedenreich ('81) and Beling ('83) treat largely of European forms while Hubbard ('80), Kellicott ('83), Leng ('94) and Lataste ('97) have contributed to our knowledge of various American types. Matheson's ('14) note on the life histories of *Psephenus lecontei* Lec. and *Stenelmis*

*To be published in the Proceedings of the Entomological Congress, held at Ithaca, August, 1928.

bicarinatus Lec. is an important contribution. A valuable account by Boving ('26) of the immature stages of *Psephenoides gahani* Champ. may be said to complete the list of important papers on the biology of the Dryopidæ. The writer's notes on *Psephenus* and *Macronychus*, also his "Bibliography of the Drypoidea," published during the past year, may perhaps be found useful by subsequent workers.

III. Descriptions of Larval Types.

The larval types here treated are nine in number. In addition, a description (in English) of the larva of the European species, *Elmis aeneus* Mull. is included for sake of comparison with related American forms. For the purposes of this paper, it was deemed advisable to emphasize only those differences which may probably be regarded as of generic significance, leaving a more complete analysis until such time as the actual identity of the species in question can be known. So far as circumstantial evidence warrants, the *probable* identity of the larva is indicated in each case.

Type 1. **Psepheninæ** (**Psephenus**).

Form flattened, elliptical, bearing superficial resemblance to a trilobite. Larva proper concealed beneath an arched carapace, formed by extension of the pleurites of the first ten body segments. "Lateral lobes," especially in mature larvæ, closely approximated, fused on basal third, each tending to overlap slightly the lobe immediately posterior. Entire peripheral border ciliated, and capable of being closely appressed to the rocks. Lateral lobes of eleventh body segment tending to become obliterated. Caudal segment (ninth abdominal) composed of a broad, flat, rectangular dorsal sclerite, and a minute ventral one, nearly four times as broad as long. Anal opening situated between dorsal and ventral sclerites of last abdominal segment.

Head visible only in ventral view, being covered dorsally by that portion of the carapace derived from the prothorax; capable of being directed either downward or forward by means of a muscular apparatus suggesting a "ligamentum nuchæ," in position and function.

Antennæ three-segmented, elongate, the first segment about equal in length to the distance between the ocelli, the second, three-fifths the length of the first, the third minute, and composed of two small segments lying side by side, the larger of which bears distally a tiny spine. First antennal segment bearing usually six hairs along posterior margin. Ocelli in two groups of six each. Labrum broad, anterior margin straight or slightly rounded, outer corners convex, each bearing a row of rather coarse spines. Mandibles large, heavily chitinized, especially

near the tips, and bearing at about mid-point of inner margin, a brush, or tuft of bristles, evidently sensory in function. Outline of mandible usually sub-triangular, but occasionally, in last stage larvæ, elongate, and appearing as though composed of a basal and a terminal portion, the sensory brush being situated on the line of division. Maxillæ large, complex, with palpi of four segments (exclusive of the palpifer). Lacinia with papillæ-like prominences, grading off into short, thick spines. Galea more or less covered with stout hair. Stipes, first and second segment of palpus bearing respectively 1, 2, 2, stout bristles which in certain individuals appear to be branched. Labium short, broad, not heavily chitinized, and bearing a pair of three-segmented palpi. Tip of third segment, like fourth segment of maxillary palpi, beset with tiny tubercles evidently tactile in function. Basal segment of palpus bearing three branched spines. Mentum quadrangular, broad, divided by only a faint suture from the more distal portion.

Legs all similar, stout, rather thickly beset with hair, and each bearing a single strong claw with short interior spine. No tarsal segments other than the claw itself. Gills ventral, arranged in five pairs, and taking origin from the posterior margin of abdominal segments 2–6. Each gill tuft composed, on the average, of ten filaments, arranged somewhat in comb-like fashion. No anal gills present. Length of mature larva, 8.5 mm. Width, 5.75 mm.

Description drawn from several specimens of *Psephenus lecontei* Lec.

TYPE 2. **Dryopinæ (Helichus).**

(Plate I, Figure 7. Plate II).

The body form elliptical-ovate, flattened, similar to *Psephenus*, but differing particularly in that the lateral lobes of the carapace are not closely joined to one another. That portion of the carapace derived from the prothorax is characterized by backward-projecting posterio-lateral angles. Dorsal surface bearing many very small tubercles, scattered irregularly over the prothorax and the lateral lobes, but in the mid-dorsal region arranged in six longitudinal rows, the outer four tending to join up anteriorly in the pattern of a broken W. Lateral lobes of abdominal segment 8 developed as in the segment preceding. Junction of pleuræ with sternum not in line with base of lateral lobes, as in *Psephenus*, but at a considerable distance nearer the mid-line. Posterior abdominal segment flattened, sub-rectangular. Dorsal sclerite slightly longer than broad, ventral sclerite two-thirds as wide and nearly as long as the dorsal one. Entire margin of animal ciliate with curiously tufted hairs, ciliation tending to disappear on the anterior and posterior border of the more anterior lateral lobes.

Head large, concealed beneath the carapace, and usually directed forward; capable of partial withdrawal into a rather elaborate, surrounding collar, composed of a reflected portion of the integument of the neck. Antennæ moderately conspicuous, composed of three segments, the first stout, and barely twice as long as broad, the second somewhat

more slender and of slightly greater diameter at the middle than at either end, and the third duplicate, as in *Psephenus*, being composed of two similar members arranged side by side. Basal segment of antennæ usually bearing three, the second, one, strong spine. Labrum nearly two-thirds as long as broad; front margin regularly convex with slight anterior medial expansion; anterio-lateral angles heavily ciliate with hair. Mandibles large, heavily chitinized, conspicuous, similar to those of *Psephenus*, with stout interior sensory filament covered with distally directed setæ, and surrounded at the base with a considerable mass of sensory hairs. Elongate type of mandible most common, especially in more mature specimens, but short, sub-triangular form also occurs. Maxillæ complex, rather membraneous, bearing small, four-segmented palpi, the distal segment being very minute. Hairs on stipes and basal segments of palpus noticeably branched. Galea without characteristic form, being roughly cuboidal, bearing distally about six, stout, curved spines, together with many lesser hairs, which cover a large portion of its surface. Lacinia tending to simulate a truncate sleeve, open along the free margin, and bordered distally with many, fairly stout spines. Labium membraneous, somewhat elaborate in structure, fully twice as long as broad, the mentum but doubtfully distinct from the palpi-bearing distal portion. Distal portion with heavily ciliate anterior margin, and with internal structure suggestive of differentiation into glossa and paraglossæ. Palpi of three segments in addition to the palpiger.

Legs similar to *Psephenus*, but characterized by the presence, on the ventral surface of the femur, of several modified spines (usually 6), each spine short, considerably thickened, and bearing many tiny processes. Claws each with a slender interior spine. Gills anal in position, arranged in three principal tufts and capable of extrusion between the ventral and dorsal sclerites of the posterior abdominal segment. Spiracles confined to eighth abdominal segment. Length of mature larva, 5.5 mm. Width, 3.5 mm.

Description drawn from several specimens supposedly *Helichus lithopilus* Germ. Most of the material at hand was collected from either Oneida or Tompkins Counties, New York.

Type 3. **Dryopinæ? (Lara?).**

(Plate I, Figs. 2, 6. Plates II, III).

Form elongate, sub-cylindrical and tapering caudally. Body segments very distinct, each appearing as though telescoped into the one preceding. Thoracic segments especially, with tergum overhanging laterally in form of a dorsal shield. Larva, in lateral view, noticeably convex dorsally, ventral surface correspondingly concave. Dorsal ornamentation of all segments elaborate, consisting of tubercles and papillæ arranged in an irregular pattern, similar for all segments. Posterior, and in part, lateral margins of each dorsal segment bearing a variable, complex row of backward-projecting processes (papillæ)

which are in turn adorned with fine spines. Ornamentation so arranged as to give effect of four longitudinal rows of large backwardly projecting processes, extending the length of the dorsum, but more conspicuous in the abdominal region. Two of these rows are sub-dorsal, two lateral. Posterior abdominal segment cylindrical at base and tapering distally; about as long as the two preceding segments taken together. Dorsal sclerite, viewed from above, terminating in two rather conspicuous, sharp processes. Ventral sclerite sub-quadrate, and bearing two elongate posteriorly directed processes on its inner (upper) surface, hooked at their tips and with many spines on basal portion.

Head roughly orbicular, directed forward, and adorned above with many tubercles of various size. Ocelli in two groups of five each, each group arranged in two vertical rows, three in the first, two in the second. Antennæ short but fairly conspicuous and noticeably hairy. First segment one and one-half times as long as broad, second more than half the thickness of the first, and one and one-half times as long. Third segment duplicate consisting of two sub-equal members lying side by side, one of which bears an exceedingly minute terminal spine, (not seen in all specimens). Labrum three times as broad as long, very spiny, lateral margins obliquely rounded, medial portion of anterior margin concave. Mandibles sub-quadrate, with deep concavity along inner margin. Inner "sensory brush" situated one-third the distance from base to tip. Tip bidentate. Outer surface of mandible very hairy, with long waving setæ. Maxillæ complex, rather heavily chitinized; cardo with a very conspicuous, sharp hook; lacinia and galea each bearing many short, thick sensory spines. Those borne on lacinia are much more robust than those on galea. Lacinia modified in the form of a truncate sleeve, open along the free surface. Stipes, near point of origin of the four-segmented palpi, bearing a considerable mass of flexible and elongate spines. Labium sub-rectangular, twice as long as broad and bearing three-segmented palpi. Mentum not to be clearly differentiated from palpi-bearing distal portion. Palpi, especially on second segment, conspicuously setaceous. Small, circular area at tip of palpus supplied with minute papillæ, serving apparently, a special sensory function. Entire margin of distal half of labium conspicuously hirsute, the longest spines occurring in the region of the palpi.

Legs stout and similar to those of other types, each terminating in a stout claw which bears internally a tapering spine. Spines present on all segments, longest on the tibia. On both femur and tibia, spines are sometimes very short and thick, but never of the "taste-bud" form found in *Helichus*. Coxæ not particularly modified for reception of femora. Gills caudal, arranged in three principal tufts and capable of being extruded between sclerites of last abdominal segment. Spiracles easily observed, situated laterally on first eight abdominal segments. Length of mature larva, 15.5 mm. Width, 2.25 mm. (Greatest expansion of prothorax).

Description drawn from several specimens collected from Yellowstone National Park, and from San Jacinto Mts., Calif.

By reason of its size and geographical distribution, tentatively assigned to *Lara avara* Lec. It might here be mentioned that according to Grouvelle, *Lara avara* is not a true Dryopid, but might better be considered as belonging to the Helodidæ. (Zaitaev '08).

Type 4. **Elminæ (Stenelmis).**

(Plate I, Fig. 8. Plate III).

Larva elongate, of the form of an attenuated hemi-cylinder, i. e., with ventral surface nearly flat, but with dorsum arched, so as to appear in cross-section semi-circular. Median dorsal line but faintly indicated; not elevated into a carina of any sort. Prothorax one and one-half times the length of the succeeding segment. Seen in dorsal view, margins of all body segments except the last appear bisymmetrically rounded, the margin of the prothorax alone being very slightly sinuate. Posterior abdominal segment sub-conical; the dorsal sclerite rather abruptly narrowed posteriorly and terminating in two sharp points. Ventral sclerite occupying posterior half of segment, of the form of a quadrangle with an equilateral triangle attached posteriorly; with two elongate, slender appendages, bearing numerous spines, and recurved at the tips. Entire dorsal surface of the larva, except the head, covered with a close sprinkling of fine tubercles, each of which tends to give rise to a minute, backwardly directed spine. These tubercles tend to be replaced by spines on posterior segments. Those spines along the posterior margin of each segment are more stout and elongate, forming a ciliate border to the segment. Larva slightly broadest in the region of the first two or three abdominal segments; diminishing slightly in size both anteriorly and posteriorly from this point.

Head large, exserted, rather conspicuous, being nearly three-fourths as broad as prothorax; with conspicuous Y-shaped epicranial suture visible dorsally. Antennæ short, composed of three segments; the first rather deeply inserted and but slightly longer than broad, the second much more slender, fully twice the length of the first and, seen laterally, more expanded at distal end than at the base; the third duplicate, being composed of two small, transparent articles arranged side by side, the one gradually tapering, the other more robust and of the same diameter throughout. No terminal spine has been demonstrated on either of these articles. Ocelli situated behind the antennæ, each group composed of apparently five units. Labrum simple, with lateral margins evenly rounded; slightly emarginate anteriorly. Anterior and lateral margins, as well as entire upper surface, beset with rather stout spines. Mandibles sub-triangular, distinctly tri-dentate, and bearing a large "taste-brush" on the inner surface at about one-third the distance from base to tip. Outer surface bearing at least two branching spines. Maxillæ small, with four-segmented palpi. Stipes, near base of palpus, bearing at least one stout branching spine. Small area on distal portion of last palpal segment provided with papillæ, evidently tactile in function. Lacinia lying close upon

galea and of the usual form, i. e., resembling a truncate sleeve, or cylinder, open along the exposed surface and adorned distally with a variable number of stout spines. Galea without characteristic form, bearing distally several stout curving spines. Labium membraneous, nearly twice as long as broad, and bearing three-segmented palpi, of which the third segment is much the smallest and bears distally a small sensory area, where are located usually four tactile papillæ. Outside of, and opposite to first palpal segment may be found, on each side, a short, stubbed spine. Mentum rather clearly bounded by a suture at the base of the palpi. Distal portion of labium evenly convex and adorned with a great number of fine, tactile hairs.

Legs composed of the usual parts and adorned with a rather scanty covering of spines. Coxæ somewhat excavated anteriorly, and thus adapted for reception of femora. Distal portion of excavation cushion-like in appearance, with a mass of small closely ranged tubercles. Claw bearing on its inner surface a slender, and sometimes curving spine. Gills caudal, arranged in three principal tufts and capable of extrusion between the sclerites of the posterior abdominal segment. Spiracles situated laterally, one pair on the meso-thorax and one pair on each of the first eight abdominal segments. Length of mature larva, 6.5 mm. Greatest width (at first abdominal segment), .91 mm.

Description drawn from several specimens taken at Walnut Creek, Michigan, and assigned to *Stenelmis* since several adults of that genus were associated with them. Also the larva of *Stenelmis bicarinatus* Lec. as figured by Matheson ('14) comes closer to this type than to any other studied so far.

Type 5. **Elminæ (Stenelmis?).**

(Plate I, Fig. 9. Plate IV).

Larva elongate, of the hemi-cylindrical form described under type 4. Viewed dorsally, the thoracic segments are seen to be expanded somewhat, giving the appearance of deep notches between the segments. Prothorax about one and two-thirds times the length of the succeeding segment, somewhat narrower anteriorly and with a faintly sinuate impression parallel to, and near each lateral margin. First six body segments of approximately equal width, the last six abdominal segments becoming gradually less in size. Median dorsal line indicated by a faint elevation, conspicuous only on the last abdominal segment, where it forms a very low median carina. Posterior segment roughly conical, terminating dorsally in two very short, blunt processes (i. e., nearly truncate as compared with type 4). Ventral sclerite occupying posterior two-fifths of ventral surface of segment, of the form of a quadrangle with an equilateral triangle appended posteriorly, and bearing on its inner surface two slender, tapering, recurved appendages, rather generously provided with spines. Dorsum of larva without ornamentation save for almost uniform sprinkling of tubercles over all body segments. Most of these tubercles are in the form of exceedingly

short, blunt, spines, directed somewhat posteriorly. Those along the posterior margin of each body segment, other than the last, tend to be bidentate, giving the effect of a row of closely ranged spines bordering the segment.

Head comparatively much smaller than in type 4, usually conspicuously exserted, and with epicranial suture usually visible. Antennæ short, but fairly conspicuous, being directed forward, and composed of three segments, the first about as broad as long, the second twice the length of the first and only half as thick, the third duplicate, consisting of two, semi-transparent articles lying side by side, the length of the longer being equal to half that of the segment preceding. Basal segment bearing two or three fairly large spines. Ocelli situated behind the antennæ, each group consisting of apparently five units. Head, just below the ocelli, on either side bearing at least two very short, modified spines of the "taste-bud" type. Labrum about twice as broad as long, somewhat concave anteriorly, and with lateral angles smoothly rounded; bearing on dorsal surface and on anterior margin, many stout spines of varying length. Mandibles elongate-triangular, heavily chitinized, bidentate at the tip. Interior surface with a hemispherical concavity, of doubtful function since it collects all manner of debris. Inner "tactile brush" situated just below this concavity, and hirsute, largely, on the upper side only. External surface of mandibles bearing usually one stout spine besides a three or four branched sensory spine of curious form. Maxillæ small, compact, bearing four-segmented palpi. Cardo boat-shaped for reception of sub-galea. Stipes long and slender, bearing two, much branched spines near base of palpus. Galea without characteristic form, adorned distally with a variable number of stout, more or less curved spines. Lacinia lying close upon galea and of the form of a truncate cylinder, somewhat constricted in the middle and open along the exposed surface; bearing distally a number of stout, curving spines. Labium small, membraneous, bearing three-segmented palpi of which the terminal segments possess each a number of very fine tactile setæ grouped at the very tip. Maxillary palpi have each, distally, a similar tactile structure. Labium with a pair of short, stout spines, situated, one just exterior to the basal segment of each palpus. Entire distal surface of labium beset with very minute papillæ, each bearing a minute hair.

Legs consisting of the usual number of parts, coxa somewhat modified anteriorly for reception of the femur, the shallow groove being bordered on either side by a tuberculate ridge. Floor of groove, near trochanter, covered with many fine, closely ranged tubercles, as in preceding species. Trochanter and femur each supplied with several short, thick, modified spines, of the taste-bud type. All segments more or less adorned with setæ of various size. Claw elongate and with a slender spine arising from interior surface. Gills caudal in position, arranged in three principal tufts and capable of withdrawal and extrusion between the sclerites of the posterior abdominal segment. Spiracles to the number of nine pairs, situated on the mesothorax and on each of the first eight abdominal segments. Length of mature larva, 5.3 mm. Greatest width (mesothorax), 0.8 mm.

Description drawn from several specimens most of which were also taken at Walnut Creek, Michigan. Tentatively assigned to *Stenelmis* because of the many structural features in which it is similar to Type 4.

Type 6. **Elminæ.**

(Plate I, Fig. 5. Plates IV, V).

Form very elongate, almost perfectly cylindrical, characteristically arched dorsally, hence ventrally concave (as seen in lateral view). Length of all abdominal segments equal to, and in the last three or four greatly exceeding their thickness. Posterior abdominal segment typically sub-conical; dorsal sclerite, as seen from above, with serrate lateral margin, terminating posteriorly in two short, pointed, lateral processes. Posterior ventral sclerite occupying distal two-fifths of ventral surface of the segment; of the form of a rectangle with a broad isosceles triangle appended posteriorly, and bearing on the inner surface the usual pair or slender, tapering appendages, recurved at the tip. Appendages more or less covered with hair, also distal portion of sclerite (interior surface). Entire dorsum of larva sprinkled with small tubercles which tend to be directed posteriorly, not a few, especially near the mid-line giving rise each to a fine spine. Tubercles arranged in an even row across posterior margin of each body segment, (except the last); each is here prolonged posteriorly in the form of a double, tooth-like spine, thus giving the appearance of a spinose border for each segment.

Head somewhat elongate, directed forward and freely movable, variously adorned with small spines; antennæ inconspicuous, being usually very closely appressed; of three segments, but appearing somewhat as though made up of four, due to the rather deep insertion of the first into an elevated antennal fossa. First true segment very slightly longer than broad, and with a scanty adornment of fairly strong spines distally, second about one and one-third times the length of the first, but only half as thick, very slightly larger in the middle than at either end, and with a few sparse hairs, distally. Third segment merely an elongate slender, tapering spine, somewhat curved and nearly as long at the second segment; in my specimens at least with no tendency to duplication! Ocelli just posterior to antennæ, with apparently five units in each group. Labrum about twice as broad as long, heavily spined, the lateral corners rounded, the anterior margin showing but a very slight tendency to concavity. Mandibles elongate-triangular, heavily chitinized, tending to become bi-dentate at the tip. Inner surface smoothly concave, but nowhere deeply excavated. Inner "sensory brush" situated at a point about one-fourth the distance from base to tip, and hirsute on its upper surface only. Maxillæ typical, with cardo concave for reception of sub-galea, palpi four-segmented, and with lacinia truncate, and open along the exposed face. Stipes, near base of palpus bearing two very stout spines, one some distance below the other. All segments of palpus bearing at least a few slender

hairs. Terminal segment bearing at the distal extremity two or three sensory papillæ. Both lacinia and galea bearing distally several very stout and somewhat curved, sensory spines. Labium more than twice as long as broad with palpi of the usual three segments. All three segments of palpi sub-equal, the distal one bearing two or three terminal papillæ. Mentum with a single large spine on each side, just below first segment of palpus. Distal end of labium covered with many small papillæ, closely and evenly arranged; each bearing a tiny sensory hair.

Legs, as compared with those of most types, rather slender, variously adorned with spines, including, on the trochanter and femur several modified into the "taste-bud" type found on *Helichus* (Type 2) and certain others. Coxæ conspicuous by reason of peculiar scaly outer surface. Anterior coxal margin deeply grooved for reception of femur, which groove is cushion-like distally, by reason of the presence of fine tubercles, and is bordered on each side by a row of heavily chitinized teeth. Gills caudal, arranged in three principal tufts and capable of extrusion and withdrawal between the sclerites of the last abdominal segment. Spiracles situated laterally, one pair on the mesothorax and one each of the first eight abdominal segments. Length of mature larva, 6.1 mm. Greatest vertical thickness (mesothorax), .45 mm.

Description drawn from specimens collected by Dr. Needham at Dark Valley, San Jacinto Mts., Calif. It is impossible to assign them to any group smaller than subfamily with the knowledge at hand. That they belong in the Elminæ is beyond question however, by reason of the many structural similarities between this and other types of the group.

Type 7. **Elminæ.**

(Plate I, Fig. 1. Plate V).

Form extremely elongate, almost perfectly cylindrical throughout. Thorax nearly as long as meso- and metathorax taken together. Posterior abdominal segment typically subconical, nearly as long as the two segments preceding and squarely truncate at the tip, i. e., with no pointed, backwardly directed prolongations. Ventral sclerite occupying distal two-fifths of posterior segment, sub-ovate in outline, and bearing on the inner surface the usual pair of elongate, tapering, and recurved appendages. Spinose ornamentation of sclerite and its appendages rather delicate as compared with many types. Entire dorsum of animal sprinkled with small tubercles, each terminating more or less distinctly in a very short, backwardly-directed spine, those along the posterior margin of each segment bearing larger spines which are thus arranged in a regular transverse row across the segment.

Head sub-orbicular, with many spines and hairs on the front, also surrounding the ocellar regions, mostly directed backward. Profile view of head suggesting a rhinoceros, the impression being due to a curious, carinate elevation involving principally the clypeus; very conspicuous. Entire head directed forward and freely movable.

Antennæ very short and robust, composed each of three segments, the first about as broad as long, and profusely adorned with long hair on the upper surface of its distal border, the second, one and one-half times as long as its greatest width, somewhat tapering, and bearing distally a very few, weak hairs, the third duplicate, being composed of two sub-ovate, semi-transparent papillæ. Ocelli situated behind the antennæ; apparently with five units in each group. Labrum short, broad, with anterior margin, and especially the rounded lateral angles bearing many stout, upturned spines which give the appearance of a "mouth brush" of generous proportions. Mandibles sub-triangular, with a slight protuberance on outer surface, at about one-third the distance from base to tip. This protuberance bears a small, branching tuft of spines and is opposite in position to the inner "sensory brush," which is surrounded at its base with a collar of short bristles. Tip of mandible distinctly tri-dentate. Maxillæ elaborate but typical, with cardo boat-shaped, adapted for the reception of subgalea, with palpi four-segmented, and with lacinia in the form of a truncate sleeve largest distally and open along the exposed surface. Both lacinia and galea bearing several stout, curved spines, those borne by galea being fewer in number, but slightly more elongate. Stipes, near base of palpus bearing three large, and at least two small tufts of branching spines. All segments of palpus adorned with at least a few hairs, the distal segment bearing two small terminal papillæ. Labium membraneous, broadest at distal end of mentum, which is easily distinguishable from the palpi-bearing distal portion. Mentum itself five-sixths the total length of labium, and less than twice as long as broad. Palpi very short, robust, of three segments, the terminal segment bearing distally a number of sensory papillæ. Mentum bearing on each side, at some distance from base of palpus, a single stout spine. Distal end of labium covered with small tubercles, each giving rise to a minute hair.

Legs robust, elaborately adorned with spines, both single and branched. Coxæ and femora each with a variable number of "sensory buds." Inner surface of coxa slightly excavated for reception of femur; outer surface with very heavy chitinous spurs, distally. Claw tending to be constricted near the middle at which point, on the inner surface, arises a branching spine. Gills caudal, arranged in three principal tufts, capable of extrusion and withdrawal between the sclerites of the posterior abdominal segment. Spiracles of the number of nine pairs, one pair on the mesothorax and one on each of the first eight abdominal segments, all situated laterally. Length of mature larva, 9.5 mm. Greatest vertical thickness (mesothorax), .76 mm.

Description drawn from specimens collected by Dr. Needham at Taquitz Valley, San Jacinto Mts., Calif., assigned to the Elminæ on the basis of structural characters. This type is interesting since it represents the extreme opposite, in almost every particular, to the form possessed by *Psephenus*.

TYPE 8. **Elminæ** (**Elmis quadrinotatus** Say).

(Plate I, Fig. 3. Plates V, VI).

Form elongate, tapering, sub-cylindrical in cross-section and with the thoracic region somewhat arched, causing the head to be directed downward rather than forward. Larva bearing dorsally three longitudinal rows of very large prominences, the median dorsal row being barely perceptible on the thoracic segments, but becoming increasingly more prominent posteriorly, the largest being that borne by the eighth abdominal segment. Dorso-lateral prominences larger on the anterior than on the posterior segments. Last abdominal segment fully twice the length of the segment preceding, roughly cylindrical at the base, tapering distally. Dorsal surface of this segment, as seen in lateral view, strongly arched and finely serrate with backward-projecting spines, tooth-like in form. Dorsal sclerite truncate posteriorly, i. e., with no sharp, backwardly-directed prolongations. Ventral sclerite ovate-elliptical, occupying nearly the entire distal half of ventral surface of the segment, and bearing on the inner surface, the usual pair of slender, tapering, somewhat recurved appendages, hairy on their basal two-fifths. Tergum of prothorax, and also of succeeding segments, to a lesser degree, expanded somewhat in a lateral direction, but not to the point of suggesting a carapace. Entire dorsal surface, including the head, beset with very small tubercles more or less uniformly distributed. Posterior margin of each body segment bordered by a row of very short, stout, closely ranged spines, arising in pairs.

Head rather elongate; freely movable. Antennæ small and inconspicuous, composed of three segments, the first scarcely longer than broad, the second more than twice the length of the first, and more slender throughout, but tending to be enlarged at the tip, the third duplicate, composed of two semi-transparent articles lying side by side, the shorter and more robust bearing distally a fine spine. Labrum sub-rectangular, with lateral angles rounded; fully twice as broad as long, the anterior margin slightly concave and sparsely covered with hair. Upper surface bearing several heavy spines. Ocelli situated just back of antennæ, with apparently five units in each group. Mandibles elongate-triangular, heavily chitinized, noticeably concave interiorly, and bearing at about one-fourth the distance from base to tip the usual sensory filament, which in this form is spined above, but not below. Tip bluntly tridentate. External surface bearing at least two curved spines. Maxillæ of usual form with four-segmented palpi and lacinia in the form of a truncate cylinder open along the free surface. Stipes near base of palpus bearing two, very conspicuous, branched spines. Distal segment of palpus with a terminal area adapted for sensory function by the presence of several delicate hairs. Lacinia and galea each with a considerable number of strong recurved, distal spines. Labium two and one-half times as long as broad, chitinized basally, but with distal portion, including palpi, almost transparent. Mentum not clearly distinct structurally from palpi-bearing portion. Palpi actually three-segmented, but appearing sometimes as four-

segmented due to the conspicuous development of the palpiger. All palpal segments somewhat beset with hair, the third bearing distally a minute sensory apparatus in the form of a few papillæ-like hairs. Entire distal surface of labium beset with many very small tubercles, each bearing a very tiny spine.

Legs of the usual number of parts, strong but perhaps more slender and elongate than those of other types. Variously spined, most conspicuous feature being the two rows of strong teeth bordering the concavity extending along the anterior surface of the coxæ. Distal half of this concavity, (which serves for reception of the femur) lined with a sort of cushion, composed of closely ranged tubercles of very small size. Claw elongate, bearing on the inner surface a delicate spine. Gills caudal, arranged in three principle tufts and capable of extrusion and withdrawal between the sclerites of the posterior abdominal segment. Spiracles situated laterally, a poorly developed pair on the mesothorax, and a conspicuous pair on each of the first eight abdominal segments. Length of mature larva, 4.75 mm. Greatest vertical thickness (third abdominal segment, including median dorsal prominence), 0.62 mm.

Description drawn from several specimens taken at various localities, mostly eastern. This species was collected by J. G. Needham at Coy Glen, Ithaca, N. Y., and reared by E. A. Richmond. Several specimens were subsequently identified as *Elmis quadrinotatus* Say.

Type 9. **Elminæ (Macronychus?).**

(Plate I, Fig. 4. Plate VI).

Form fairly elongate; sub-triangular in cross-section due to a tendency of the tergum to expand somewhat laterally and also to a perceptible elevation along the median dorsal line. Posterior abdominal segment nearly as long as the three preceding, sub-conical in form, the dorsal sclerite terminating posteriorly in two short, blunt processes. Entire segment (viewed laterally) nearly straight along the basal two-thirds of the ventral surface, but dorsally, arched and minutely serrate. Ventral sclerite occupying distal third of ventral surface of the segment, sub-ovate in outline, and bearing, on the inner surface, the usual pair of elongate, tapering appendages, recurved at the tip and more or less covered with spines. Entire dorsum of larva beset with small tubercles, many of which, especially in the median-dorsal region bear each a minute, backwardly directed spine, usually double. Tubercles along the posterior margin of all body segments (except the last) arranged in a regular row and bearing each a pair of sharp, posteriorly-directed teeth.

Head very closely joined to prothorax and evidently not capable of very free movement; mouth parts directed downward. Antennæ small, of three segments, the first about as broad as long and bearing at least two rather stout spines, tending to be more or less branched; the second nearly twice the length of the first and about half as thick,

tending to possess slightly greater diameter at either end than in the middle; third segment duplicate, composed of two sub-equal, transparent articles lying side by side, one of which appears distinctly spatulate. Ocelli situated posterior to the antennæ, in two groups, one on either side of the head, each composed of five units. Labrum about twice as broad as long, heavily spined, the anterio-lateral angles rounded, and with a slight, but perceptible concavity to the anterior margin. Mandibles elongate-triangular, inner margin with a deep concavity, situated just above the sensory filament; sensory filament hairy on upper side only. Outer margin of mandibles bearing one or two short branching spines. Tip of mandible bluntly bi-dentate. Maxillæ of usual form; with sub-triangular cardo adapted for reception of galea, with four segmented palpus and with lacinia in the form of a truncate cylinder open along the free surface. Galea globoid in outline. Lacinia and galea each bearing distally several stout, curving spines. Stipes near base of palpus bearing two stout, elongate spines, one situated some distance below the other. Terminal segment of palpus with at least three distal papillæ. Labium large, nearly two and one-half times as long as broad. Mentum rather easily distinguishable from distal portion, and bearing on each side just below base of palpus, a single large, curving spine. Palpus three segmented, but borne on a well developed palpiger, hence appearing sometimes as though composed of four segments. Distal segment of palpus bearing usually three small transparent papillæ, confined to a small circular distal area. Entire distal end of labium covered with many small closely ranged papillæ, each giving rise to a tiny spine.

Legs rather elongate, variously adorned with spines, most conspicuous among which are the very large, blunt, bifurcate, distally directed and heavily chitinized scale-like teeth found in the coxæ. Interior (anterior) surface of coxæ broadly grooved for reception of femora, which groove is cushion-like, distally, by reason of a massing of small tubercles within a restricted circular area. Gills caudal, in three principle tufts and capable of extrusion and withdrawal between the sclerites of the last abdominal segment. Spiracles situated laterally, one pair on the mesothorax and one on each of the first eight abdominal segments. Length of mature larva, 3.75 mm. Greatest width, (prothorax), .74 mm.

Description drawn from three specimens collected in Taquitz Valley, San Jacinto Mts., Calif., but applying almost equally well to larvæ found associated with *Macronychus glabratus* Say at Ithaca. This description, until further knowledge is available, may be assumed to apply to *Macronychus parvulus* Horn, the western representative of this genus.

To my knowledge, the foregoing types cover most of the important variations in form encountered in the United States. There is a gap, however, between the type assigned to *Helichus*

and the other, sub-cylindrical or sub-triangular types, and in order to better illustrate the gradation of form within the family, I have introduced at this point a brief description of the European larva, *Elmis aeneus* Mull.

Elmis maugei Bedel. var. **aenea** Mull.

Larva elongate and noticeably flattened dorso-ventrally. Thorax much larger than the rest of the body with prothorax as long as the meso- and metathorax taken together. Prothorax emarginate anteriorly for the reception of the head. All segments of thorax rounded bi-symmetrically on the sides. Abdomen forming an isosceles triangle, with the base anterior; regularly attenuated and composed of nine segments which diminish gradually in size. Margins of abdominal segments expanded into thin lateral lobes, as are those of the thorax; those arising from the abdomen, however, being not rounded, but prolonged posteriorly. Last abdominal segment truncate, conical, and slightly notched posteriorly. Ventral sclerite, or operculum, small, sub-triangular, and provided at the extremity with two appendages, recurved ventrally. Border of all body segments with exception of the last is dilated, thin, semi-transparent and adorned with a ciliate fringe, rather complex in structure. Central portion of dorsum noticeably punctured, also posterior two-thirds of lateral processes.

Head small, but entirely visible, with two pale dorsal lines united into a Y posteriorly. Antennæ short, yellowish, composed of three segments; the first broad and rather deeply inserted, the second more elongate (3 x), more slender, and bearing distally the duplicate third segment, which consists of two small articles of less than half the length of the second segment, and lying side by side. The superior of these two articles is terminated by a small spine. Ocelli, of the number of five on each side, placed behind the antennæ, and arranged in two rows, the first of three, the second of two units. Mouth bordered by a transverse labrum, feebly sinuate laterally, provided with spines which are very large at the base, having the form of a jagged scale; of these there are ten altogether. Mandibles triangular, enlarged at the base and terminating in two strong bifid teeth. On the inner surface one finds an appendage in the form of a tendril, hairy along its upper surface. Maxillæ in two lobes, each of which (galea and lacinia) bear distally a stout brush of spines. Palpi two-segmented, the second terminated by two tiny appendages. Labium trapezoidal, hairy in front, bearing two small, biarticulate palpi.

Legs short, but strong and robust, composed of a coxa, trochanter, femur, tibia, and lastly a tarsus which terminates sharply in the form of a curved claw and bears on the under surface a stiff spine. Gills caudal in position, arranged in three principle tufts and capable of extrusion between the sclerites of the posterior abdominal segment. When extruded one tuft lies directly caudad, the others lateral to the first. Spiracles distributed as follows: One pair on the anterior border

of the metathorax;* one pair on each of the first eight abdominal segments. Length of mature larva, 3.5 mm. Width, (greatest lateral expansion of thorax), 1.0 mm.

Description adapted largely from Laboulbene ('70). This species may be said to share honors with *Psephenus lecontei*, in regard to popularity in the literature.

IV. Discussion.

(a) *Comparison of larval types: correlations of structures with habit:*

There exists a remarkable tendency to gradation of type from the flattened, elliptical, limpet-like *Psephenus* to the elongate, nearly cylindrical forms predominating in the Elminæ. Between extreme types one finds hardly any superficial similarity, other than in the legs, which are, throughout the group almost invariably of a common pattern, always ending in a single stout claw adapted for clinging to the sub-stratum. One can hardly say that the gradation of form includes *all* the types with which we are concerned, or that we can arrange them in a single straight forward series. Such an attempt, indeed, would be contrary to our ideas regarding the evolution of most present-day forms, which appear to represent merely the tips of branches, the stems from which they have arisen being long since extinct. Even so, if we select a certain four of the known types, namely *Psephenus*, *Helichus*, *Elmis* (European) and *Stenelmis* we shall have this gradation excellently illustrated: The closely joined lateral lobes of *Psephenus* are no longer overlapped when we encounter them in *Helichus*. They are reduced to still less useful processes in *Elmis* and are entirely lacking in *Stenelmis*. Likewise the head in both *Psephenus* and *Helichus* is concealed beneath the expansion of the prothorax. It is set rather deeply into the prothorax in *Elmis*, but is nevertheless entirely visible from the dorsal surface. In the *Stenelmis* group, however, the head is freely movable in all directions. The fact of greatest importance is that perfect homology of structure may be recognized throughout the series, the form of the first three being apparently due to

*According to Erichson ('48) the first pair of spiracles occur on the mesothorax. I am inclined to think that this is correct and that Laboulbene's interpretation is erroneous.

more or less elaborate modification of a simpler plan of structure such as is found in the fourth.

The one serious obstacle in the tracing of homologies, concerns the position of the respiratory organs. This problem, though puzzling, appears to be of fundamental significance. In *Psephenus* alone, are the gills ventral, in all the others caudal. Le Conte, more than once mentions *Psephenus* as having its chief branchial filaments in the anal region, but in this he was apparently deceived. Neither Kellicott nor I have been able to find gills in this position. The very similar larva of *Psephenoides* (native to northern India) has, however, the three-tufted anal gills characteristic of *Helichus*, *Elmis*, and related genera. This feature alone would tend to indicate that *Psephenus* is of a separate line of descent, related not so closely to either *Helichus* or *Elmis* as those two are to one another. Such an assumption is further supported to some extent by the fact that in *Psephenus* the lateral lobes, with the exception of the prothoracic expansion, seem to be composed entirely of modified pleurities, while in *Helichus* and *Elmis* the tergum plays a much more important part. It is here interesting to note that the genus *Eurypalpus* (*Psephenus*) was considered an anomalous one by Le Conte, Harris and others, before the larva was ever known. Harris critized Le Conte freely for placing it with the Parnidæ. Leading authorities now consider the genus as standing quite apart,in its capacity as type genus of the Psephenidæ.

Another very interesting feature relates to the structure of the posterior abdominal segment, which is strikingly similar in most of those larvæ which have gills caudal in position. In *Helichus* alone (of American genera) are there no appendages on the inner surface of the ventral sclerite to correspond with the two slender more or less recurved processes found in all the others. Why they should here be absent, is difficult to understand. Dufour ('62) figures the not distantly related *Potamophilus* with conspicuous appendages in this position. Correlated with the lack of appendages is the fact that the caudal segment of *Helichus* closely resembles that of *Psephenus* in being broad, flattened and definitely forming part of the carapace by which the greater portion of the larva proper is covered. But the ventral sclerite in *Psephenus* is so reduced in size that appendages are virtually impossible. In all the rest, that is in those forms in which appendages are present,

the posterior segment is subcylindrical, usually tapering posteriorly, and with the ventral sclerite attached as a sort of trap-door upon the posterior portion of the ventral surface.

Bearing in mind these fundamental differences in structure we shall now attempt to show how adaptation to environment is well illustrated by the body-form of each type studied: Both *Psephenus* and *Helichus* are principally stone dwellers, the margins of their carapaces when firmly appressed to the stone being excellent aids in clinging, no matter how swift the current. They are thus able to roam at will over exposed surfaces without danger of being swept away, and by reason of the difficulty with which they may be detached, they are not an easy prey for predators. There is no doubt that *Psephenus* greatly exceeds *Helichus* in this adaptability since the more perfectly joined seams of its carapace not only make suction more complete, but seem also to exclude all silt, whereas *Helichus* can surely have but little natural protection against the dangers of muddy waters. It has the ability, it is true, to extend and to withdraw its gills, as have all the others of the family in which the gills are caudal in postion, and this is no doubt protective to a degree, but the fact that *Psephenus* is the most universally distributed, at the same time most abundant in number of individuals of any genus in the group, argues well for its superior ability to meet the vicissitudes of changing environment. In the experimental work conducted in connection with this investigation it was found practically impossible to maintain alive, those types with caudal gills, due to the unavoidable amount of silt which accumulated in the hatchery troughs; but *Psephenus*, on the other hand, survived most satisfactorily, and on one occasion, when, as a result of rising water an accumulation of one-fourth inch of mud and silt covered the stones on which the larvæ were feeding, a careful washing away of the deposit revealed the entire colony alive and apparently normal. The hairy margins of their lateral lobes serve evidently as most excellent filters, to the end, that beneath the body, where the water is made to flow past the gill-tufts by the perpetual rythmic motion of the posterior abdominal segment, there is practically no possibility of sufficient contamination to affect harmfully the respiratory apparatus. It is conceivable that they are thus able to mine beneath a layer of silt, feeding on whatever algæ may be attached to the rock, for an indefinite period of time.

The European *Elmis*, in spite of its tendency to imitate *Helichus* in the possession of lateral lobes, is obviously not able to make as good use of them as either *Psephenus* or *Helichus*. It has, however, gotten away from the cylindrical form to a very considerable extent and is assuredly better adapted for currents than are the more elongate types. It is well suited for the head-up-stream position so commonly observed in Plecopterous and Ephemerid nymphs, its backwardly-directed lateral lobes in every way suggesting adaptation for this, but we cannot conceive that it would be a successful competitor of *Psephenus* on smooth rocks, in swiftly flowing water.

All the remaining types, with certain negligible exceptions, lack any development even comparable to the carapace idea, and the situations in which they are found quite naturally reflect their structure. *Macronychus*, in particular, is a dweller of wood, rather than rock. It seeks out the crevices and makes shallow burrows for its comfort and security. Various others of the Elminæ, are, it is true, collected from stones, but they always take advantage of quiet down-stream surfaces, or of niches, or of clinging vegetation to render their position secure. All have a tendency to curvature of the body, the dorsal surface being convex, the ventral concave (as seen in lateral view), and of this they take advantage, employing the abdomen as a sort of large, seventh foot to assist in maintaining their hold.

One marked advantage, may be correlated with the lack of a carapace, and that is the possession of a freely movable head. Both *Psephenus* and *Helichus* have the head concealed. In all probability they can perceive through their carapaces various intensities of light (always reacting negatively when the stimulus is strong) but for intimate knowledge of their surroundings they must rely wholly on the tactile function of antennæ and palps. The larva of *Psephenus* in fact seems to derive its nourishment simply by scraping up everything that the surface of the rock affords, passing through the intestine that which proves indigestible. It is not conceivable that the sense of vision plays any real part in food selection. *Helichus* appears to be somewhat better equipped in this particular. Besides the fact that its carapace tends frequently to be less heavily chitinized, especially over the head region, there are, on the dorsum of the abdomen four yellowish spots, which possibly

may be more sensitive to light than other portions of the carapace. In relation to the apprehension of food, we should not fail to mention the presence of several curious bud-like processes, arranged along the under surface of the femora, in this genus. It is possible that by means of these little structures, the larva tastes, or at least explores freely with its legs, and is thus able to obtain a more intimate knowledge of its surroundings. These modified spines occur also on the legs of certain Elmid types.

It has already been mentioned that *Elmis* (European) possesses a head, which, though not capable of great freedom of movement, is at least directed forward, and is perfectly visible dorsally. It therefore represents a transition between the cylindrical types with head freely movable, and those in which it is concealed beneath the expanded prothorax.

Turning now to less conspicuous features of structure, we find that the antennæ, throughout the group, tend to be of a uniform type, consisting of three segments, the third always diminutive, and in most cases duplicate. The duplicate condition was first interpreted by Erichson ('48). This author states that the larger member, usually bearing a minute spine distally, is the true third segment. The other is construed as an appendage (modified spine) of the second antennal segment, and tends to closely resemble the true third joint. Beling ('82) in his description of the larvæ of *Pomatinus substriatus* Mull. and *Parnus auriculatus* Panz (nec. Geoffr.) mentions but a single spine as constituting the third segment in these two forms. I should have been inclined to regard his descriptions as erroneous, had I not discovered an American form the antenna of which possesses but a single member in this position. (Type 6 of this paper). The identity of this larva is at present unknown to me, but it appears to be allied with the Elminæ rather than the Dryopinæ. We may therefore regard the single or double condition of the third segment as of at least no more than generic significance. It is perhaps also worthy of note that *Psephenus*, with its concealed head, has, in proportion to other structures, the most elongate antennæ in the entire group, while type 7, the most cylindrical and elongate form studied, possesses the extreme of shortened and thickened antennal segments.

These facts all tend to show that those portions of the anatomy most freely exposed, and hence most liable to be affected by environmental conditions manifest greatly divergent modifications as we pass from one type to another. It is in the mouth parts, on the other hand, that we find most strikingly illustrated that "certain air de famille," to which Perez ('63) refers.

Concerning the labrum we need say but little save that it bears almost always a considerable number of tactile setæ. The mandibles, however, are of particular interest, for here we find the most striking similarity throughout the group. In fact the greatest differences encountered in the mandibles were between individuals of the same species, rather than between types. All have mandibles subtriangular in outline, with a conspicuous condyle on the outer angle of the basal margin. Somewhere on the inner margin, usually about one-third the distance from base to tip may be found some form of brush-like organ, either a tuft of coarse spines (*Psephenus*) or, more frequently, a finger-like filament bearing many hairs or setæ, and in miniature resembling somewhat the tail of a fox. This structure is always present, and may very probably function in the selection of food. Between this tactile organ and the tip, the mandible is always more or less excavated or grooved, the pattern of the concavity being typical for each form, as shown in the figures.

It was in *Psephenus* and *Helichus* however that the most interesting fact was brought out in connection with mandibular form, namely that two types of madibles are possible in the same species. These have already been mentioned in the foregoing descriptions. Plate II, figure 5 shows an interesting condition, illustrative of this point, which was observed in each of two individuals of the *Helichus* series. Both these larvæ were evidently about to molt. It will be seen that the more nearly triangular mandible, belonging to the younger stage, is about to be replaced by a more elongate type, which appears almost as though made up of two parts, a broad basal, and a tapering distal portion. Both these types are to be found in *Psephenus* also, where the triangular form is predominant, even in the mature larva. Kellicott ('83) however, figures the elongate mandible as typical for *Psephenus*, and merely mentions that the mandibles of younger larvæ tend to be shorter. This

would seem to hold true for *Helichus*, much better than for *Psephenus*, since all my early dissections of the former, being made of larger individuals, disclosed only elongate mandibles, and it was not until an earlier stage was examined that the condition shown in the figure was discovered. Taking into consideration the apparent absence of mandibles *intermediate* in outline, we can scarely hope to account for these findings by assuming that the shorter mandibles represent merely elongate types that have been worn down by continual scraping against the surface of the rocks. This point, in particular, needs further study.

The maxillæ, like the mandibles, though complex and difficult of interpretation as to constituent parts, are essentially similar throughout the group. All have four-segmented palpi, the distal member of which bears at its tip a sensory apparatus, sometimes minute, sometimes consisting of definite number of fairly conspicuous papillæ, but apparently serving a similar function in all forms. Cardo, stipes, lacinia sub-galea and galea are each represented but the basal parts tend frequently to be so fused that only lacinia and galea may be recognized with certainty. These both bear distally various spines, papillæ, and other sensory apparatus. Lacinia is often curiously modified, tending usually to take the form of a truncate sleeve, open along the free margin. This tendency is most pronounced in the Elminæ, is not at all indicated in *Psephenus*, and may prove to be of minor importance at least, as a group character.

The labium of each type, likewise, bears a fairly close resemblance to that of every other. The only conspicuous differences are those of proportion, which of course is always to be correlated, with the shape and characteristic attitude of the head. Thus we find the labium shortest and broadest in *Psephenus*, and most elongate in the type referred to *Macronychus*, but the fundamental similarity of structure cannot be ignored. In nearly all cases the labium tends to be membraneous rather than heavily chitinized. The line of demarcation between the mentum and the palpi-bearing distal portion (ligula) is rarely more than indistinctly present. The distal region itself, though tending in certain types to be differentiated into glossa and para-glossæ, in most cases appears as a more or less unified structure. The palpi are always three-segmented,

though the palpiger, (as in types 8 and 9) may appear at times very much like a basal segment.

The tips of all labial palpi studied, and the distal margins of the labia themselves are always provided with sensory papillæ, or their equivalent in the form of tiny setæ or spines.

(b) *Natural grouping within the family on basis of larval characters: interpretation from an evolutionary point of view.*

We are usually safe in asserting that group characters of primary importance tend to be found in obscure places where they have had little opportunity to be affected by the influences of environment. Thus we have found, running through this family a great similarity in the structure of mouth parts, even down to minute details, while general body form, position of head and of respiratory apparatus, show great modification along more or less diverging lines. True, the food habit is similar for all, there being none but that are vegetable feeders in aquatic situations, a fact which has probably tended to preserve the fundamental character of these structures, or, at most to modify all in somewhat similar fashion. If this were not the case, we might be at considerable loss to fasten upon characters which would show clearly the family relationship of all forms studied.

When it comes to the matter of dividing the family into minor groups on the basis of larval structure, we have but a single striking character, namely, the position of the gills. *Psephenus* alone has these ventral in position. Thus it may be assumed that whatever the ancestral family type may have been, there apparently occurred, in the phylogeny of this group, a very early split, one line developing the ventral gills, while all the rest developed (or perhaps retained) a caudal respiratory apparatus. The latter type of gills being capable of withdrawal into the body, were in a measure, protected, and but little secondary modification of body form appeared in either the Dryopid or the Elmid group. In *Psephenus*, however, the remarkable adaptation in the form of a pseudo-carapace made its appearance, serving not only to increase the ability of the animal to cling to rocks in swiftly flowing water, but also as an almost necessary protection from the silt, which must have wrought havoc with the exposed gills before they became thus protected, if, indeed, the carapace did not appear before

fixed gills replaced the spiracles. The suggestion is entirely speculative, but it is not impossible that the Psephenid stock was once equipped with caudal filaments also, such as are found in *Helichus*, and that these were not lost until conditions became favorable for more efficient use of the ventral equipment.

As for the carapace of *Psephenoides*, also the fairly pretentious lateral expansions of *Helichus* and their lesser homologues in the European *Elmis*, we can say only that this type of body form appears to be an adaptive structure developed independently in each group in response to external conditions. In all these forms it is useful in giving the larva somewhat of a limpet-like outline, a very desirable asset in itself, in manouvering beneath a strong current, but its adaptation as protection for the respiratory system is not found except in *Psephenus*.

Thus we see that our assumed "gradation of form" lacks any great significance except to show rather subtle tendencies of relationship, which may be partially elucidated as follows. In the Psepheninæ, *all* species possess the carapace-like modification in its most extreme form. In the Dryopinæ which we generally regard as lying between the Psepheninæ and the Eliminæ, we find, so far as is known, the elliptical form confined to the two genera, *Psephenoides* and *Helichus*, and perhaps to only certain species of the latter. Beling ('82) has the larva of *Pomatinus substriatus* Mull., also that of *Parnus auriculatus* Panz. as cylindrical in form. But the genus *Pomatinus* is not now regarded as distinct from *Helichus* (Zaitzev, '08) and *Dryops* (*Parnus*) is certainly most intimately related to *Helichus* also. In addition, the large larva tentatively called *Lara* (type 3 of this paper) is far from resembling the *Helichus* type mentioned above, yet *Lara* has long been accepted as a close relative of both *Helichus* and *Potamophilus*. But the latter, as shown clearly by Dufour ('62) and Perez ('63) is not dissimilar from *Macronychus*, which is an Elmid genus!

Turning therefore to the Elminæ we note that the usual form is here even more cylindrical, with little or no hint of modification of the pleuræ into lobes, yet in the very genus supposed to be typical for the group, are species exhibiting a modification strongly suggesting *Helichus* (*Elmis aemeus* Mull., and *E. volkmari* Panz.). The apparent absence of similar

larvæ in America, where adults belonging to the same genus are of frequent occurrence, is assuredly of some significance in this connection. The only American *species* of which the larva is known is *Elmis quadrinotatus* Say. This larva is the sub-cylindrical, warty-backed form designated in this paper as type 8. Comparison of the descriptions will disclose little suggestive of close relationship between this larva and that of *Elmis aeneus*. Surely then, in both Dryopinæ and Elminæ, the tendency to elliptical body form cannot have more than generic significance, if indeed it has that.

Because of this nearly parallel performance of the two related subfamilies, (Dryopinæ and Elminæ), we are left without a character or combination of characters which will separate the larvæ of these two groups. This is, in a measure disappointing, but on the other hand it confirms clearly the assumption that the Psephenid stem was separate long before there existed any marked tendency for the main line to become diversified, and that there has never been a second split quite so profound as that which was responsible for the differentiation of ventral and caudal respiratory organs.*

Whatever interpretation may be placed upon the various facts brought out, it at least seems definitely assured that in *Psephenus* the greater specialization has occurred in the *larva*, which, by extraordinary modification of structure, has most successfully adapted itself to the environment in which it is found. Probably it is the larva alone which takes food and it is a well known fact that in the larval form only is the species able to withstand the winter. The greater portion of the life history is spent in the larval stages, and the adult is important only for the perpetuation of the species. In other words the larva has acquired, while the adult has lost, various important functions.

At the other extreme, let us consider *Macronychus*. Surely, the larva is here comparatively primitive. There are prac-

*Regarding the relationships of the Psepheninæ, Dr. Boving holds a somewhat different opinion, preferring, by reason of the ventral gills and the absence of a cloacal chamber, to derive this group from the Ptilodactylidæ. In recent correspondence Dr. Boving mentions receiving, from China, an unidentified larva, elongate-cylindrical in outline, but possessing long gills beneath the abdomen, and without a cloacal chamber. This Dr. Boving interprets as representing a connecting link between *Psephenus* and *Eurypogon* (of the Dascylloidea). The genus *Eubryanax* (hitherto listed with the Dascylloidea) should undoubtedly be transferred to the Psephenidæ as Dr. Boving suggests, since its larva is structurally very similar to that of *Psephenus*.

tically no modifications of structure to assist in clinging, other than six good legs, and it is therefore quite natural that slowly, rather than rapidly moving waters are preferred. The habit of making shallow burrows in rotten wood may be compensation for the lack of specialized body form, but at the same time the ability of the larva to move about is thereby obviously limited. In this genus it is the *adult* which is the more perfectly adapted for life on submerged surfaces. They cling tenaciously to submerged wood with their enormous claws, two to each of their six sprawling legs. These beetles live long, and are known to survive the winter. (West, '29*c*).

Now the general similarity between the larvæ, and also between the adults of most of the Elminæ, is strong evidence that we have here not only a single genus but indeed a whole group which is finding itself, by specialization of *adult*, rather than larval structures. These beetles, being provided with means of taking their air with them, seem to be quite unrestricted in their movements when submerged. They roam wheresoever they will, so long as the substratum is favorable for their feet. They are forsaking the aerial for the aquatic life. Dufour ('34) reports certain individuals of *Macronychus quadrituberculatus* Mull. as having but rudimentary wings, while other individuals have wings normally developed. In several dissections of *Macronychus glabratus* Say., I found only the rudimentary type present!

A further analysis of the relationships in this group must await not only added information on matters of embryology and internal anatomy, but also more detailed knowledge of life histories, that there may be established, beyond doubt, the identity of all forms under consideration. Only when this data becomes available, shall we be able to discuss satisfactorily the relationships of *genera* and *species*.

VI. ANALYTICAL KEY TO A FEW LARVAL TYPES.

(Including Six European Forms).

1. Gills ventral in position, consisting of five pairs situated on posterior margins of abdominal segments 2–6. . . . . *Psephenus* Hald. (Type 1 of this paper, *P. lecontei* Lec.; American).
   Gills caudal in position, capable of extrusion and withdrawal between dorsal and ventral sclerites of posterior abdominal segment. . . . . 2.
2. Head not visible dorsally, being covered by an extension of the prothorax. . 3.
   Head usually free, sometimes set more or less deeply into the prothorax, but always distinctly visible dorsally. . . . . 4.

3. Lobes of the carapace tightly joined except for distinct lanceolate apertures not far from the free margins. Outline broadly oval, the combined thoracic and combined abdominal segments about equal in size, forming two almost symmetrical halves.....*Psephenoides* Gahan.
(*P. gahani* Champ.; Northern India).

Lobes of the carapace distinctly separate at all points. Outline elongate-oval, the anterior segments more expanded than the posterior. Length to breadth as 5.5–3.5.....*Helichus* Er.
(Type 2 of this paper, presumably *H. lithophilus* Germ.; American).

4. Tergum, in all body segments except the last, produced laterally in combination with pleuræ into conspicuous, more or less backwardly directed lateral lobes..... 5.

Body form other than as above, in cross-section usually sub-cylindrical, rarely sub-triangular, but in no case with tergum produced laterally to form conspicuous lobes..... 6.

5. Form elongate-oval, gradually attenuated posteriorly. Color of first two abdominal segments not differing perceptibly from that of the others, *Lathelmis* Reitt.
(*L. volckmari* Panz., as *Elmis volkmari;* European. Description after Rolph).

Form more compact, usually smaller than the above type. Head set more deeply into prothorax, abdominal segments becoming more rapidly smaller posteriorly, lateral processes more sharply pointed and more strongly curved. Dorsum of first two abdominal segments lighter in color than the segments following.....*Elmis* Latr.
(*E. Maugei* Bedel var. *aenea* Mull as *E. aeneus;* European. Description after Rolph).

6. Third antennal segment consisting of but a single member, usually a mere tapering spine..... 7.

Third antennal segment duplicate, consisting of two sub-equal members arranged side by side upon distal end of second segment..... 9.

7. Prothorax usually from one-fourth to one-third longer than meso- and meta-thorax taken together..... 8.

Prothorax scarcely equal to combined length of the two succeeding segments.
(Type 6 of this paper; American).

8. Larger species, of darker coloration. Longitudinal furrows conspicuous along anterior margin of meso- and metathorax and first eight abdominal segments. Three small spines present on dorsal surface of last two segments.....*Helichus* Er.
(*H. substriatus* Mull. as *Pomatinus substriatus;* European. Description after Beling).

Smaller species, of lighter coloration. Longitudinal furrows present as in preceding species, but much weaker. Dorsum of two posterior abdominal segments lacking the three small spines.....*Dryops* Oliv.
(*D. ernesti* Des Gozis, as *Parnus auriculatus* Ill.; European. Description after Beling).

9. Abdominal segments except the last (thoracic also, to a lesser degree) each bearing three very large more or less backwardly directed processes, one situated on the median dorsal line, the others dorso-lateral in position.....*Elmis* Latr.
(Type 8 of this paper, *E. quadrinotatus* Say; American).

Abdominal segments sometimes ornamented with small tubercles of spiny filaments, but never bearing large processes as above..... 10.

10. Antennæ short and thick, sub-conical in form. Second segment not exceeding in length the first.
(Type 7 of this paper; American).

Antennæ more or less elongate. Second segment always more slender than the first and usually all of twice as long..... 11.

11. Posterior abdominal segment (viewed dorsally) notched on caudal margin a distance equal to two-fifths the length of the entire segment. Mature larvæ with four distinct longitudinal dorsal carinæ.....*Potamophilus* Germ.
(*P. acuminatus* Fabr.; European. Description after Dufour).
Posterior abdominal segment (viewed dorsally) never notched for a distance greater than one-sixth the length of the entire segment. Not more than a single, median-dorsal, carina..... 12.

12. Legs possessing a rudimentary tarsal piece at the inner juncture of the tibia and the claw, (not visible when viewed from above),
Macronychus Mull.
(*M. quadrituberculatus* Mull.; European. Description after Perez).
Legs without such rudimentary tarsal piece..... 13.

13. Dorsum conspicuously ornate with backwardly directed fingers or filaments, each with a covering of small spines; larger species..*Lara* Lec. (?)
(Type 3 of this paper, presumed to be *L. avara* Lec.; American).
Dorsum unadorned, or at most with an even sprinkling of fine tubercles, which give a granular appearance to the surface; smaller species..... 14.

14. Form elongate, suggesting a hemi-cylinder, the ventral surface being somewhat flattened, the dorsal roundly arched. No perceptible elevation of the median-dorsal line into a longitudinal carina. Head usually exserted and freely movable..... 15.
Form more compact, sub-triangular in cross-section, ventral surface being rather flat, as compared with the strongly arched dorsum, which bears a low, but perceptible median carina for at least part of its length. Head closely joined to thorax and evidently not capable of great freedom of movement.....*Macronychus* Mull. (?)
(Type 9 of this paper, presumably *M. parvulus* Horn, also true for *M. glabratus* Say; American).

15. Posterior abdominal segment (viewed dorsally) with caudal margin distinctly notched, the lateral margins terminating in two sharp points,
Stenelmis Duf.
(Type 4 of this paper, similar to *S. bicarinatus* Lec. as figured by Matheson; American).
Posterior abdominal segment (viewed dorsally) pseudo-truncate, i. e., with caudal margin but very slightly emarginate, suggesting at most, a bluntly bilobed condition.....*Stenelmis* Duf.
(Type 5 of this paper, very similar structurally to type 4; American).

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Type 7, mature larva, lateral view. Fig. 2. Type 3, head of mature larva, dorsal view. Fig. 3. Type 8, (*Elmis quadrinotatus* Say), mature larva, lateral view. Fig. 4. Type 9, (*Macronychus?*), mature larva, dorsolateral view. Fig. 5. Type 6, mature larva, lateral view. Fig. 6. Type 3, (*Lara?*), mature larva, lateral view. Fig. 7. Type 2, (*Helichus lithophilus* Germ.), mature larva, dorsal view. Fig. 8. Type 4, (*Stenelmis?*), mature larva, dorsal view. Fig. 9. Type 5, (*Stenelmis?*), mature larva, dorsal view.

PLATE II.

Larval types 2 (*Helichus*) and 3 (*Lara?*).

Fig. 1. Type 2, antenna. Fig. 2. Type 2, leg. Fig. 3. Type 2, mandible, elongate type. Fig. 4. Type 2, labrum. Fig. 5. Type 2, mandibles of successive stages, showing marked change of form. Fig. 6, Type 2, mature larva, ventral view, (marginal ciliation omitted). Fig. 7. Type 2, labium. Fig. 8. Type 2, maxilla. Fig. 9. Type 3, leg (prothoracic). Fig. 10. Type 3, antenna.

PLATE III.

Larval types 3 (*Lara?*) and 4 (*Stenelmis?*).

Fig. 1. Type 3, maxilla. Fig. 2. Type 4, labium. Fig. 3. Type 4, maxilla. Fig. 4. Type 3, ventral sclerite of posterior abdominal segment, from within. Fig. 5. Type 4, labrum. Fig. 6. Type 4, ventral sclerite of posterior abdominal segment, from within. Fig. 7. Type 4, leg, (prothoracic). Fig. 8. Type 4, dorsal sclerite of posterior abdominal segment, from below. Fig. 9. Type 3, mandible. Fig. 10. Type 4, antenna. Fig. 11. Type 4, mandible. Fig. 12. Type 3, dorsal sclerite of posterior abdominal segment, from below. Fig. 13. Type 3, labium.

PLATE IV.

Larval types 5 (*Stenelmis?*) and 6.

Fig. 1. Type 5, maxilla. Fig. 2. Type 5, leg. Fig. 3. Type 5, labium. Fig. 4. Type 6, mandible. Fig. 5. Type 5, dorsal sclerite of posterior abdominal segment. Fig. 6. Type 5, ventral sclerite of posterior abdominal segment, from below. Fig. 7. Type 6, leg. Fig. 8. Type 5, labrum. Fig. 9. Type 5, mandible. Fig. 10. Type 5, mature larva, ventro-lateral view. Fig. 11. Type 5, antenna. Fig. 12. Type 6, labrum. Fig. 13. Type 6, antenna.

PLATE V.

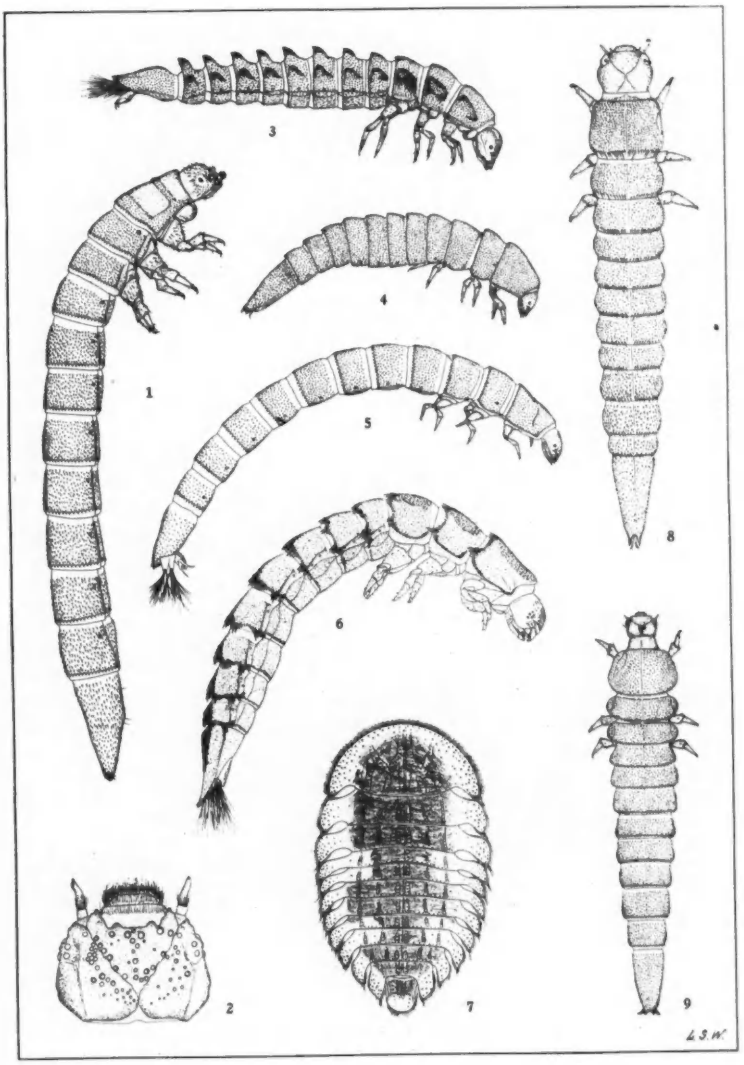
Larval types 6, 7 and 8 (*Elmis quadrinotatus* Say).

Fig. 1. Type 6, labium. Fig. 2. Type 6, ventral sclerite of posterior abdominal segment, from within. Fig. 3. Type 7, maxilla. Fig. 4. Type 7, antenna, from below. Fig. 5. Type 7, labium. Fig. 6. Type 7, leg. Fig. 7. Type 6, maxilla. Fig. 8. Type 7, ventral sclerite of posterior abdominal segment, from within. Fig. 9. Type 7, Dorsal sclerite of posterior abdominal segment, from below. Fig. 10. Type 7, mandible. Fig. 11. Type 8, antenna. Fig. 12, Type 8, leg. Fig. 13. Type 6, dorsal sclerite of posterior abdominal segment, from below.

PLATE VI.

Larval types 8 (*Elmis quadrinotatus* Say) and 9 (*Macronychus?*).

Fig. 1. Type 9, dorsal sclerite of posterior abdominal segment, lateral view. Fig. 2. Type 9, antenna. Fig. 3. Type 9, ventral sclerite of posterior abdominal segment, from within. Fig. 4. Type 8, mandible. Fig. 5. Type 9, leg. Fig. 6. Type 9, mandible. Fig. 7. Type 9, labrum. Fig. 8. Type 8, ventral sclerite of posterior abdominal segment, from within. Fig. 9. Type 8, labrum. Fig. 10. Type 8, maxilla. Fig. 11. Type 8, labium. Fig. 12. Type 9, labium. Fig. 13. Type 9, maxilla.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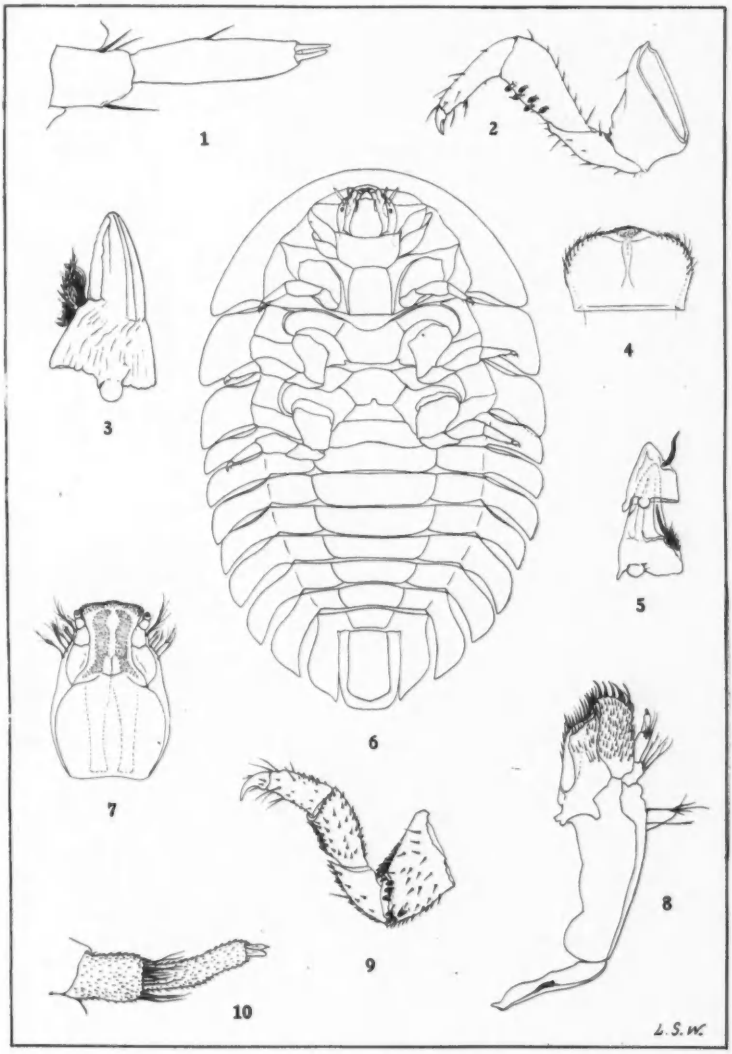
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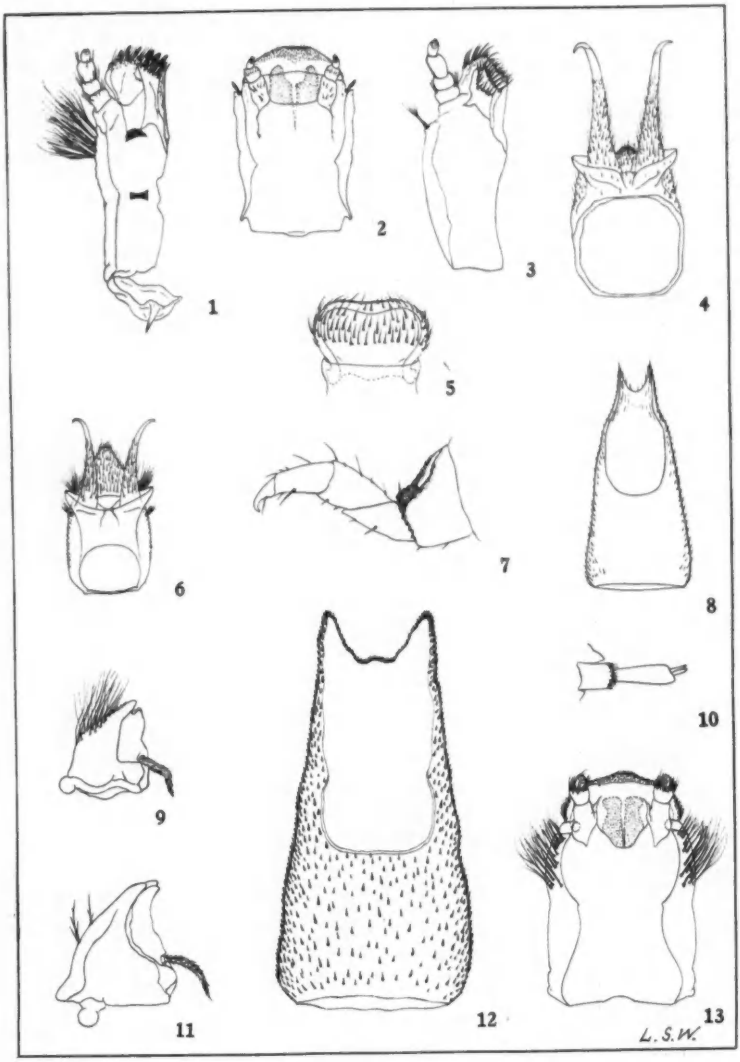
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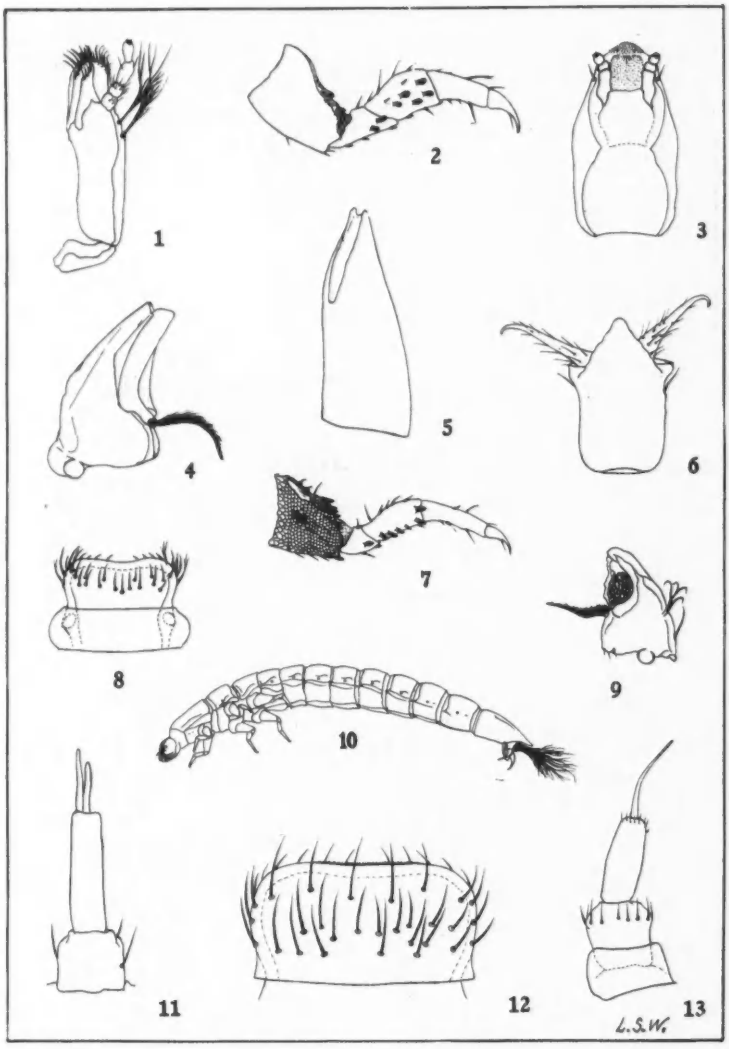
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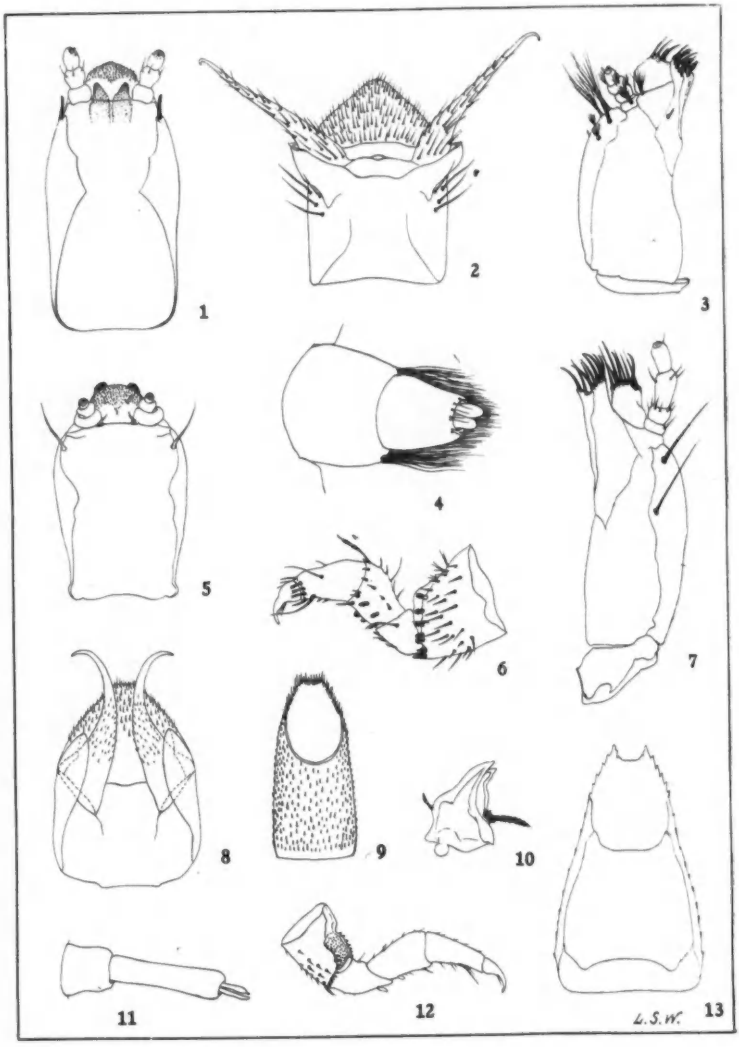
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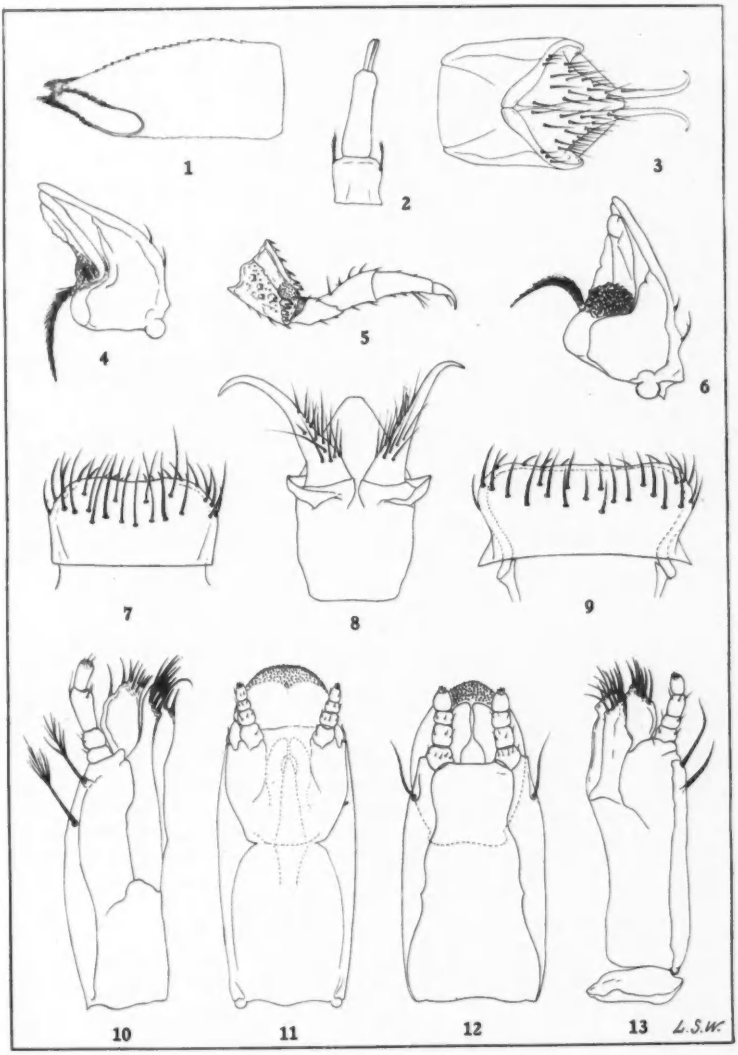
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TWO NEW SPECIES OF MALLOPHAGA.

R. O. Malcomson,
University of Illinois.

While doing research work at the University of Illinois under the direction of Professor C. L. Metcalf two new species of Mallophaga were discovered.

These determinations have been checked by Dr. H. E. Ewing.

Myrsidea bonariensis n. sp.

(Fig. 1).

Two specimens a male and a female were taken from the skin of *Molothrus bonariensis* (Cabanis), the Argentina cowbird. This skin is in the University of Illinois Museum. The skin bears no data.

The measurements of this species are as follows:

	Male	Female
Body length	1.04 mm.	1.22 mm.
Body width	.36 mm.	.52 mm.
Head length	.26 mm.	.26 mm.
Head width	.36 mm.	.41 mm.

Description of the Female.—The head is semi-circular in front with two short hairs on the margin, one on either side of the cephalo-median point. The antennal fossæ are long and curve inward with the inner margin very dark and distinct. The antennæ are four-segmented, the distal segment is capitate but irregular in form. The antennæ lie entirely concealed from dorsal view. The ocular fringe is very distinct and is composed of stiff curved hairs. The prothorax is narrow, but the pterothorax is as wide as the head, and contains on each caudo-lateral margin a single spine. The abdomen is clothed with many short hairs and spines on the lateral margins extending as far toward the median line of the body on both dorsum and venter as the heavier chitinized parts extend. Short spines are present on segments 1 to 4, inclusive.

On the last abdominal segment of the male there are two pairs of exceedingly long hairs.

This species closely resembles *Myrsidea cyrtostigma* (Kellogg and Chapman), which was taken from several passerine birds of Hawaii. The measurements are very nearly the same. The pterothorax is much longer than that of *boneriensis*. The

short spines on the abdomen in *boneriensis* are confined from the 1st to the 4th segments inclusive, while in *cyrtostigma* the spines are located on the 2nd to the 8th segments.

Type and allotype material has been deposited in the Illinois State Natural History Survey Collection.

Philopterus cristata n. sp.

(Fig. 2).

Six specimens, two males and four females were taken from the skin of the blue jay, *Cyanocitta cristata cristata* (Linné).

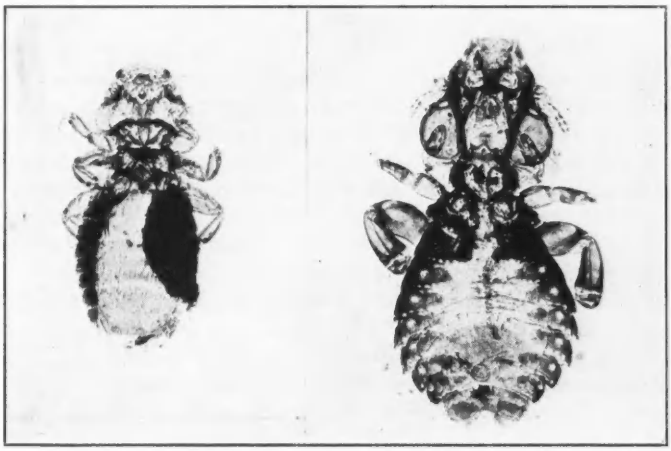

Fig. 1. *Myrsidæ bonariensis*, n. sp.
Fig. 2. *Philopterus cristata*, n. sp.

The skin from which these were taken is in the Illinois Natural History Survey Collection. Since taking these specimens I have found the blue jay to be very heavily infested with this particular species of louse.

Description of Female.—The body length is 1.69 mm. and body width is .79 mm. The head length and width is the same, .57 mm. The forehead is broad. The clypeus has two hairs in front, one on each side. The signature is very prominent, extending to a point caudad of the mandibles. The ocular emargination is shallow and broadly curved. The first segment of the antennæ is exceedingly large, the second segment is the longest, being as long as two of the three

distal segments. The trabeculæ are large, extending to the end of the first antennal segment. They curve caudad and in toward the body. The mandibles are large. The eyes are prominent and contain a single hair. Just below the eyes and on the lateral margin is a second long hair. The temporal margin on each side bears three long hairs. The prothorax is comparatively small, with a long hair in the caudo-lateral angle on each side. The first pair of legs is short with exceedingly large femora. The pterothorax is almost as large as the head. There are four long hairs in the caudo-lateral angles of the pterothorax. Twenty-four long pustulated hairs are visible from the dorsal view along the caudal margin of the pterothorax. The lateral blotches on the abdomen resemble those of *Philopterus quiscali* (Osborn). The eighth abdominal blotch extends unbroken from one side of the body to the other. The ninth abdominal segment is divided into two triangular chitinous areas with a constriction curving cephalad. The abdomen is very generally covered with long hairs.

This species is very similar to *Philopterus thryptocephalus* (Kellogg and Paine), which was taken from *Gracilus gracilus* an Old World bird, which has been classed with the jays.

It differs from *thryptocephalus* in the shape of the head. The head of *cristata* is just as long as broad, while the head of *thryptocephalus* is broader than it is long. In *thryptocephalus* the cephalic angles of the clypeus are rounding and the cephalic margin of the clypeus is curved, while in *cristata* the angles are more acute and the cephalic margin of the clypeus forms a straight line.

Type and allotype material has been deposited in the Illinois State Natural History Survey Collection.

BOOK NOTICE.

LABORATORY AND FIELD ECOLOGY, by Victor E. Shelford. Williams and Wilkins. pp 608, text figs. 219.

In this case the reviewer is deviating from the inflexible (?) rule of the editorial office that no books are reviewed unless free copies are sent the Editor. This volume is of such outstanding value to all experimental entomologists, which term includes all men in the economic game, that it must be called to the attention of all members of the Society. It is a compendium of research previously done and particularly of apparatus of use in experimental work. We prophesy that for some years to come it will be the Bible in every experimental laboratory. It is a method book comparing with Lee's Vade Mecum in the histological laboratory. It has a bibliography of 1,012 titles constantly referred to by number in the text, which makes it extremely useful in opening up the whole field of literature. The price seems large, but it is worth every cent of it. C. H. K.

A STUDY OF RESPIRATION AND RESPIRATORY ORGANS OF THE RAT-TAILED MAGGOT, ERISTALIS ARBUSTORUM L.

(Diptera: Syrphidæ).*

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INTRODUCTION.

It is, of course, well known that among insects there are two general types of respiratory apparatus: the open type in which from one to ten pairs of spiracles function, and the closed type in which there are no functional spiracles and in which the insect obtains air by diffusion through a membrane. Of the two the latter type is much more rare. The majority of larvæ of aquatic insects have either tracheal gills or blood gills present as means of obtaining air from the water in which they live. According to Imms (5) these gills may be the only means of respiration in a typically closed system, but often they occur in connection with open spiracles in certain insects (larval Culicidæ for example).

The Eristalis larvæ, breathing normally through one pair of spiracles at the end of the long, tail-like breathing tube, would be classed with those insects having the open system. At certain times these larvæ, commonly known as Rat-tailed Maggots from Reaumur's "vers a queue de rat" extrude from the anal aperture several slender, finger-like appendages which usually wave about with a rhythmical motion. These are exceedingly well supplied with tracheæ which arise from the main respiratory system.

The resemblance of these finger-like processes to tracheal gills and their location in connection with the rectum have earned for these structures the name "rectal gills" from some authors. Buckton (2) however has suggested that they represent rudiments of the curious rectal glands of the adult fly. The writer believes no investigator has ever submitted any

*Contribution from the Department of Zoology and Entomology, Iowa State College.

positive evidence to show these structures to be part of the respiratory system.

The present problem therefore was attacked with a dual objective: first, by means of close observation and experimentation to determine the nature of the respiratory organs and the means of respiration in this insect; and second, to discover, if possible, a connection of the above-mentioned finger-like processes with the respiratory function and thus demonstrate beyond a doubt that larvæ of Eristalis do have both open and closed types of respiratory apparatus.

The larvæ for this study were found living in great numbers in the foul ooze and decaying animal matter which flowed down a small stream from an abattoir and fertilizer plant at Boone, Iowa.

The writer wishes to express his gratitude to Dr. B. B. Fulton and Dr. W. H. Wellhouse for suggesting the problem and especially to the latter, under whose direction the work was done, for kindly aid and helpful criticism.

Historical.

According to Vinal (19) the foundation work which furnished the basis for all modern work on the subject of insect respiration was the elaborately illustrated monograph of Straus-Durckheim (1828) on the cockchafer, *Melolontha vulgaris* L.

As early as 1738 Reaumur (14) seems to have observed that Eristalis larvæ possessed two large tracheal trunks which got their air supply through a pair of spiracles at the end of the long, tail-like appendage. He had noted also the anterior stigmatic horns as parts of the respiratory system and likewise had seen the retractile, finger-like processes protruding at times from the anal aperture.

Miall (12) in 1895 observed the plumose setæ surrounding the tip of the breathing tube and in addition mentioned the three sections into which the breathing tube is divided. He undoubtedly erred in his statement that the large tracheal trunks connect with non-functional spiracles at the anterior end of the body.

Buckton (2) observed the finger-like projections from the rectal region of *Eristalis tenax*, but appeared not to have been positive that the vessels within these had a connection with the tracheal system. He concurred with Miall in the belief

that the main tracheal trunks do not open anteriorly in the larvæ.

The work of Wahl (1900) gives a most detailed and complete account of the tracheal system of *Eristalis tenax*. His descriptions and drawings of that species indicate a close similarity in anatomy of respiratory system with that of *Eristalis arbustorum*, the species which furnishes the subject for the present paper. This investigator concluded that the posterior spiracles are the only openings to the tracheal system and that therefore this insect has the metapneustic type of respiratory system. The writer believes this to be an error because tests performed on larvæ of *Eristalis arbustorum*, demonstrated conclusively that there is a pair of functional spiracles at each end of the body. It seems highly improbable that species so similar in other respects should differ in this respect.

Description of the Insect.

The Larva.

Like all other larvæ of this genus and of some other genera whose larvæ are fitted for aquatic existence, the larva of *Eristalis arbustorum* L. is peculiar in having the long, retractile, tail-like breathing tube at the end of which the posterior spiracles open. The breathing tube is in three sections, each of the two distal sections of which is capable of telescoping within the segment proximal to it (Plate I, Fig. 1). The distal one is necessarily much the smallest in diameter, is considerably sclerotized and stiffened, and has at its extremity eight minute, feather-like setæ (Plate I, Fig. 1, 2, and 3). Apparently a waxy or oily secretion on these setæ keeps the tip of the breathing tube from being easily wet at any time and keeps water from entering the spiracles. At the anterior end of the larva are two small, horn-like projections through each of which opens the forward end of one of the two main tracheal trunks (Plate I, Fig. 4 and 5).

The body proper of the grown larva is approximately thirteen millimeters long and three and one-half millimeters wide. The breathing tube varies in length from fourteen millimeters, while in a normal, telescoped position, to fifty or more millimeters, when fully extended. In general shape the body is sub-cylindrical and bluntly rounded at the anterior

end. See Plate I, Fig. 1 and 5. There are six pairs of short, blunt prolegs each bearing several sclerotized claws. In addition to the six pairs of prolegs there is another pair of similar structures far forward on the body immediately below the mouth. It is believed that the members of this pair do not represent true locomotor structures, but rather are modifications of the folds below the oral opening and are used more in feeding than in locomotion.

The Tracheal System of the Larva.

With the exception of the more primitive insects it could be said that normally an insect having the open type of respiratory system has at least two main tracheal trunks which extend nearly from end to end in the body cavity and open to the exterior by a variable number of paired spiracles along the sides of the body. This view, of course, does not recognize origins of parts.

The larva of *Eristalis arbustorum*, essentially a highly specialized animal, has apparently undergone some decided modifications in respiratory apparatus to fit its mode of existence. Since this insect is an aquatic or semi-aquatic creature, it has not been able to make use of the ordinary spiracles of the typical holopneustic insect, but has been confronted with the necessity of obtaining a supply of air while buried from one-half inch to two or more inches below the surface of mud or water.

The most obvious elements of the tracheal system of *Eristalis arbustorum* consist of two longitudinal tracheal trunks with two main tracheal connections between them. These two connections are the *anterior commissure* and the *posterior commissure* as seen on Plate II, (*Atc* and *Ptc*). At the anterior end of each longitudinal trunk is an ear-like *stigmatic horn* (Plate I, Fig. 4a and Plate II). These horns serve as the forward openings of the tracheal system; that is, as anterior spiracles. At the posterior end of each of the longitudinal trunks, which in this case is at the distal end of the long, tail-like breathing tube, there is also a spiracle with one or more openings (Plate I, Fig. 1, 2, and 3).

Description of Tracheæ.

Each longitudinal tracheal trunk has a diameter of about two-thirds of a millimeter (665 microns) at its greatest diameter as viewed from the dorsal or ventral side (Plate II). A lateral view makes it seem considerably smaller since the enlarged portion normally is somewhat flattened dorso-ventrally. Beginning at the base of the stigmatic horn each trachea is nearly round and has a diameter of about one-sixth of a millimeter and maintains this diameter posteriorly until it gradually enlarges to the full diameter of the longitudinal trunk. Relative sizes of the remaining parts of the tracheal system may be seen by referring to the various plates.

Plates II and IV were drawn from specimens somewhat distended in order to more clearly show the various elements of the tracheal system. Fig. 5, Plate I is included to show the normal positions of the main parts of the tracheal system.

No attempt has been made to follow the finer ramifications of the tracheæ which extend to the body-wall to determine whether they supply air to muscles or hypodermal cells.

Terminology of Parts.

Choice of a satisfactory scheme to follow in the terminology of parts of the respiratory system has been a considerable problem with the writer. It was originally planned to follow the terminology adopted by Wahl (20) but this was found to be too cumbersome. It was suggested by Dr. C. H. Kennedy that an attempt be made to homologize the parts of the tracheal system of this insect after the scheme set forth by Lehmann (10), but for various reasons this did not seem feasible except in small part. The scheme finally chosen (with some variations) is that developed by Kennedy (6) and which is based on a study of naiads of the Zygoptera.

Kennedy's conception of the homologization of parts of the tracheal systems of insects is somewhat as follows: the principal elements of tracheal systems as we find them in most insects may be considered as modifications of hypothetical primitive units, a pair of which occurred in each segment of the hypothetical primitive insect. Each one of these units consisted of the following major parts (1) a spiracle, (2) a spiracular pit, (3) a spiracular trunk, (4) an anterior dorsal

connective, (5) a posterior dorsal connective, (6) an anterior spiracular connective, (7) a leg trachea, and (8) a ganglionic trachea. In addition to these there are also several minor tracheal connections. According to this scheme of homologization, all tracheal trunks and parts which extend through more than one segment of the insect body are to be considered as being made up of parts of the hypothetical primitive units joined together in series. This conception (as far as possible) including the nomenclature adopted by Kennedy is followed in this paper. A sketch to show the parts of this hypothetical primitive unit has been included. See Plate I, Fig. 10.

Homologies of Tracheæ.

Dorsal Tracheæ.—Since the larva of *Eristalis arbustorum* does not have functional spiracles except at the ends of the body, there is considerable variation from the hypothetical type of tracheal apparatus. In addition to the two pairs of visible spiracles, the location of eight more pairs of atrophied spiracles can be determined with ease. Plate IV, *k* indicates one of these atrophied spiracles with its non-functional spiracular pit.

The anterior dorsal connective and posterior dorsal connective of each spiracle-bearing segment combine to make up the large *longitudinal tracheal trunks* which are clearly represented on Plates II, III, or IV. The tips of the anterior dorsal connectives and posterior dorsal connectives, which Kennedy found remained distinct in the zygopterous naiads, have apparently coalesced in pairs in this instance (Plate IV, 1-8). The writer therefore believes that in *Eristalis arbustorum* these should be called merely *dorsal connectives*. It may be noted however that in all but the first two pairs of these (Plate II, 1 and 2) one part proceeds somewhat anteriorly to the body-wall while another part proceeds posteriorly (Plate II, 3-8). It should be noted also that all save the first two pairs of tips provide minor commissures (Plate II, *h*) between the two main longitudinal tracheal trunks. The additional function of supplying air to the dorsal portion of the fat-body* is likewise performed by all except the anterior two pairs of these tips.

*The dorsal portion of the fat-body lies close beside the heart. It was suspected that this organ was supplied with tracheæ from the same tracheal branches as the fat-body, but no connections could be found in any of the larvæ dissected.

Only the bases of these fat-body tracheæ are indicated (Plate II, *e*). These bases are also indicated on Plate IV.

Ventral Tracheæ.—The *spiracular pits* which likely should be considered to serve as points of origin for all tracheal branches in the insect tracheal system are atrophied in the present case as has been noted. This seems to have caused the *spiracular trunk* (Plate I, Fig. 10, *spt* and Plate IV, *C*) to take on this function. In addition to giving rise to the dorsal connectives already mentioned, it serves as a point of origin for the *anterior spiracular connective* (Plate IV, *j*) which proceeds cephalad in each segment to join with the *leg trachea* (Plate IV, *p*) to form a section of the *lateral trunk*.

The *sternal trachea* (Plate IV, *n*) in each segment does not arise from the ganglionic trachea (*o*) as found by Kennedy in the Zygoptera. Rather, it has shifted down the leg trachea where it has an independent point of origin. The *ganglionic trachea* (*o*) does not arise from the spiracular pit, but has also migrated posteriorly down the leg trachea before it branches off. This interpretation reverses the serial arrangement of these two trachea in each segment as compared with their respective positions in the hypothetical segment. It should be explained at this point that the ganglia in *Eristalis arbustorum* do not retain their segmental positions, but are all coalesced far forward almost beneath the brain. See Plate III, *Soe*.

The arrangement of ganglionic and sternal tracheæ just described is easily seen in connection with all the spiracular trunks with the exception of the most anterior one. The exception in this case is that an accessory ganglionic trachea is present (Plate I, Fig. 6, *o'*). The anterior and posterior latero-tergal tracheæ do not have independent points of origin on the anterior spiracular connective and leg trachea respectively as determined by Kennedy. Instead, the writer believes these to have both migrated back onto the spiracular trunk where they have their bases in common. This compound base divides into the *anterior latero-tergal trachea* and *posterior latero-tergal trachea* (Plate IV, *s* and *m*) as it approaches the body-wall. See also Plate II, *s* and *m*.

Visceral tracheæ.—Tracheation of the internal organs of this insect is elaborately provided for. Kennedy found tracheation of the internal organs to be largely fortuitous in the Zygoptera. Such is by no means the case with *Eristalis arbustorum*.

The term "*visceral tracheæ*" as used by Lehmann (10) seems to the writer to be the best available term for use here. Plate III shows the number and location of tracheæ from the right, main, longitudinal trunk to the various internal organs. Each spiracle-bearing segment has at least one main trachea (*B*) extending to some part of the alimentary system. Each spiracle-bearing segment with the exception of *I* and *X* has also a smaller tracheal connection (*A*) to supply air to the fat-body and Malpighian tubes.

For want of better names these visceral tracheal branches will be known here as *visceral trachea A* and *visceral trachea B* in each spiracle-bearing segment. It should be noted that segment *I* (Plate III) has no visceral trachea *A*. Attention is here called also to the *accessory visceral trachea* (Plate III, *Ba*) which plentifully supplies the pharynx with air. A branch of this trachea extends far caudad to supply tracheæ to the ganglionic mass (Soe) and to form a cross-connection with its mate of the opposite side of the body.

The Retractile Processes.

Whether or not the retractile processes (Plate I, Fig. 1 and 7) function as part of the respiratory system remains a question with the writer. This point will be discussed further elsewhere.

The peculiar form of these structures may be observed on Plate I, Fig. 7 where they are illustrated in an extended position outside the body of the larva. It must be remembered that the larva can, at will, withdraw these structures by turning each part inside out and withdrawing the entire group of parts through the anal opening.

Two large tracheal branches, the homologies of which are not clear, arise from a point on the longitudinal trunk (Plate III, *X*) and extend into the basal part of the retractile processes (Plate I, Fig. 7, *ba*). These large tracheæ branch many times, sending tracheal connections into the smaller apical pieces (*ti*). No anastomosing of tracheæ could be observed in any part of the retractile processes.

Technique of Dissection.

In observing the general anatomy of the tracheal system, dissections were made in a 5 per cent chloral hydrate solution after the larvæ had been killed in this solution or in hot water. Insect pins of "minuten" size were used to hold the dissected specimen in a small depression made in a wax pan. Good success was also experienced with larvæ killed in alcohol and later injected with pure glycerine. Dissections were then made in glycerine. In nearly all cases a Spencer binocular microscope with 10x or 17x oculars and 25 mm. or 32 mm. objectives was used.

For getting details of the finer ramifications of the tracheæ as shown in Plate II or Plate III, a modification of a method used by Wahl (20) was found quite satisfactory. This procedure as carried out consisted of taking the larvæ previously injected with glycerine and re-injecting them with a mixture of two parts glycerine and one part Beale's carmine solution. After from ten to twenty-four hours the larvæ could be dissected. All parts of the tracheal system were usually pink in color and comparatively easy to see. This stain colored the muscle tissue red which helped to distinguish strands of this tissue from tracheæ. For the finer work it was found best to place the dissected specimen on a microscope slide under the highest power of the binocular microscope. A microscope light was then placed beneath the specimen in order to get light directly through it from below.

Results of Various Tests.

Resistance to Lack of Oxygen.

Observations of larvæ in their natural habitat indicated that they were apparently able to live in a situation where oxygen was none too abundant. In order to test larvæ of *Eristalis arbustorum* in comparison with common aerial insects, an ordinary laboratory suction pump and bell jar fitted with mercury pressure tube were procured in order to create as nearly a perfect vacuum as possible. Within the bell jar were placed living specimens of the following insects: cockroaches (genus undetermined), wireworm beetles (*Melanotus communis*), house flies (*Musca domestica*), codling moth larvæ

(*Cydia pomonella*), and larvæ of *Eristalis arbustorum*. Each species was placed in a cotton-stoppered, glass vial, the Eristalis larvæ having also water in their vial. By pumping, the pressure was reduced to a point varying from zero to one-half centimeter of mercury. This partial vacuum was kept constant until the last insect ceased activity. Below are listed the species of insects in their order of resistance from the standpoint of time. The time listed after each species indicates the period of time which elapsed from the beginning of the experiment until activity of the insect ceased. Tissues and organs of the insects were not examined for any possible physical effects due to the reduced pressure.

Cockroaches	½ minute
Melanotus communis	1 minute
Musca domestica	3 minutes
Cydia pomonella	5 minutes
Eristalis arbustorum	20 minutes

The comparatively high resistance to lack of oxygen on the part of the Eristalis larvæ may be actual, or it may be due to the fact that the oxygen contained in the water in which the larvæ were allowed to remain furnished a slight supply of oxygen to these larvæ during the first part of the test. Much bubbling of the water was observed as soon as the pressure was reduced. This bubbling increased in violence directly as the pressure was reduced until finally the water became very cool. Reduction of rate of metabolism due to the lower temperature may have caused the greater resistance of these larvæ.

Resistance to Excess Carbon Dioxide and Oxygen.

In an effort to determine the effects of excesses of such gases as carbon dioxide and oxygen on the respiratory organs and on the respiratory process, a series of tests was run.

Oxygen gas was prepared by heating manganese dioxide and potassium chlorate and catching the resulting oxygen gas by displacement of water in a bottle.

Carbon dioxide was prepared in the ordinary way by treating calcium carbonate with dilute hydrochloric acid.

In the comparative tests the Eristalis larvæ were of necessity left in a small quantity of water and the bottle of gas inverted over them. Only two species of insects were available with which to compare the Eristalis larvæ. These were a small

species of ground beetle (*Agonoderus pallipes*) and larvæ of one of the Datana moths (*Datana* sp.).

A summary of three tests is given in Table I below:

TABLE I.

RESISTANCE TO OXYGEN AND CARBON DIOXIDE.

SPECIES	OXYGEN	CARBON DIOXIDE
Agonoderus pallipes	Excessive activity, scraping antennæ, raising elytra, etc. Not killed.	Stiffness and dragging of legs, followed by total inactivity in five minutes.
Datana sp.	No unusual activity or ill effect noted.	Immediate vomiting of yellow juice. No activity except quivering, at end of one minute. Death after six hours.
Eristalis arbustorum	Usual activity, no change after eighteen hours. No efforts to obtain air.	Remained near surface of water. Repeated efforts to shoot air tubes to surface for air. Sluggish after one-half hour. Slight activity at end of three hours. Apparently dead at end of four hours. An apparent derangement of internal organs noted.

Inspection of results listed in Table I shows that the effects of carbon dioxide were much slower to appear in *Eristalis arbustorum* than in the other insects tested. The reason for this is hard to ascertain unless it is due to the large reserve supply of air present in the large tracheal trunks. The apparent derangement of internal organs was not investigated further because it appeared to have no direct bearing on the problem.

Method and Rate of Respiration.

The fact that insects obtain a sufficient supply of air through their spiracles has been more or less taken for granted without much question as to what makes the air enter the tracheæ or what causes the left-over gases to pass out. Probably the work of Lee (7) on respiration in Orthoptera has been one of the most serious attempts at an explanation of the mechanics of the respiratory process in insects. Lee states that Acrididæ have both inspiratory and expiratory spiracles present.

On several occasions a living larva of *Eristalis arbustorum* was placed in the cell of a micro cell-slide with the cell filled with water, but with a cover glass in place. This arrangement put the larva in a virtual water prison. After a few minutes in this predicament, there were always considerable nervous squirmings of the larva and numerous attempts to get the tip of the breathing tube into contact with the atmosphere. If the cover glass was moved slightly to one side so as to expose a small area of water to the air, the tip of the breathing tube soon came in contact with this area and breathing was resumed. In every case, at this point, there was an almost immediate cessation of activity of the body as a whole, but a distinct internal respiratory activity was begun. The large tracheal trunks commenced a definite and more or less periodical activity. The large spiral taenidia of the tracheal trunks (Plate I, Fig. 8) suddenly flattened in a manner likened to the flattening of the spirals in a coil spring.* Plate I, Fig. 9 will illustrate better what happened. It can easily be seen that this alone would tend to force the contained air or other gases from the main tracheal system either to the outside or into the tracheal branches. However, in addition to this movement, there was also a shortening of these main trunks coincident with the flattening. Obviously this also would tend to empty the contents, and we might consider these two movements to constitute one exhalation or expiration. Following this action there was a resumption by the tracheal trunks of their original form, but this action took place more slowly than the expiration. The interval from one exhalation to the next was approximately two seconds. It must be remembered that this could not be considered a normal breathing rate since all of these observations were made immediately following short periods during which the larva had been imprisoned away from air. The muscles or motivating force which caused the respiratory activity of the tracheal trunks defied detection.

*Since the investigations on which the present paper is based were completed there have appeared two papers by M. O. Lee: "The Function of the Air Sacs in Holopneustic Insects," in Science, LXIX, pp. 334–335, March 22, 1929; and "Respiration in the Insects" in Quarterly Review of Biology, IV, pp. 213–232, June 1929. Doubtless the function of the enlarged tracheal trunks in *Eristalis arbustorum* and allied species is the same as Lee suggests for air sacs, namely, a mechanical aid to respiration in allowing a considerable volume of air to be inhaled and exhaled.

Barlow (1) observed that respiration in dragon-fly adults varied from a very few movements per minute to as high as one hundred eight per minute. His conclusions were that the respiratory movements in the dragon-fly were subject to considerable variation in force and rate and that they were always quickened by exercise, emotion, rise of temperature, galvanism, and mechanical irritation.

Since Swammerdam in the seventeenth century discovered the presence of air sacs in insects, it has been generally assumed that their function is mainly for storage of quantities of air. To the writer it seems plausible that the enlarged portion of the tracheal system in this particular insect may be an adaptive structure serving the same purpose or purposes as air sacs in other insects. In view of the observations recorded above regarding the mechanics of the respiratory process in the tracheal trunks, it seems possible that the air sacs in other insects may function in the pumping process in a manner similar to the pumping in *Eristalis arbustorum*.

Function of Anterior Stigmatic Horns.

Metcalf (11) says that Syrphid larvæ typically have both anterior and posterior spiracles. Buckton (2), reporting his observations on *Eristalis arbustorum* larvæ, says he was never able to trace a tracheal connection to the opening of the anterior respiratory cornua. These structures are to be called stigmatic horns in the present paper in preference to Buckton's term. Metcalf takes exception to Buckton's statement and, in support of his view, states that if a larva is submerged and compressed, bubbles of air may be seen to form in connection with the tooth-like lobes (of the stigmatic horns). Wahl (20) makes the simple statement that there are posterior spiracles only in *Eristalis tenax* and proceeds on the assumption that he is dealing with a metapneustic insect.

The writer has not observed that the larvæ of *Eristalis arbustorum* ever normally use these anterior stigmatic horns for respiration. Certainly the larvæ while buried in mud in their natural habitat could not use them for respiration. To settle the question as to whether they are true spiracles or not, the following test was performed with several larvæ. A thick colloidal material was prepared by mixing cherry-gum with water. Each larva was placed in this and its actions noted.

Apparently the material offered so much resistance that the breathing tube (posterior) could not be raised to the surface for air. After considerable squirming the larva arose head first to the surface and placed the anterior stigmatic horns in contact with the atmosphere. At this instant in every case the larva ceased squirming and respiration began. The respiratory process in these tests took place in precisely the same way as described in the account previously recorded (p. 741) concerning the rate of respiration. The only observable difference was that, in that case, air was received from the posterior spiracles whereas, in this case, air was received from the anterior spiracles.

In order to determine whether respiration took place at a normal rate through the anterior stigmatic horns, respiration counts were made. The following table represents successive counts made on two different larvæ in the cherry-gum material. The counts listed in column A were made during the first few minutes after the larvæ had succeeded in bringing their anterior stigmatic horns into contact with the atmosphere following a period of submergence. The counts listed under column B were made during the first few minutes following a similar period of submergence. In the latter case, however, the larvæ had to be mechanically assisted in bringing the ends of the breathing tubes to the surface.

TABLE II.

COMPARISON OF RATES OF RESPIRATION.

	Respiratory Movements per Minute	
	A	B
	Through Anterior Spiracles	Through Posterior Spiracles
Larva No. 1	24	22
	22	24
	22	22
	18	20
Larva No. 2	18	24
	18	18
	18	16
	12	16

No very marked differences can be detected in the rates of respiration. Undoubtedly, then, we might consider the

anterior stigmatic horns to be structures which at one time may have been normally used for respiration, at least part of the time by this insect, but which at present are used only when necessity demands. It is easily seen, then, that this insect has the amphipneustic type of respiratory apparatus instead of the metapneustic as some authors have suggested. However, regardless of this fact, this insect normally functions as a metapneustic form only.

Function of Retractile Processes.

Several of the tests already reported in this paper were planned partly with the idea of determining whether or not the retractile processes (Plate I, Fig. 1 and Fig. 7) had any connection with the respiratory function. These tests as they apply to this phase of the problem will now be discussed.

Discussion of Tests.

Resistance to lack of oxygen.—It was thought that, if the retractile processes acted as supplementary respiratory organs, then, by placing the creature in an environment lacking oxygen, these organs would be brought into play. As far as could be observed none of the larvæ tested under these conditions (p. 739) attempted to use the retractile processes to supplement the oxygen supply.

Resistance to Carbon dioxide.—The larvæ, used in this series of three tests (p. 740) when placed in carbon dioxide were not observed by the writer to make any attempts to use the retractile processes for respiration. It seems probable that in their natural habitat an excess of carbon dioxide might occur. This test was planned with the idea of imitating this natural condition if it does exist.

Method and rate of respiration.—It will be recalled that in this test (p. 741) the larvæ were placed in a small quantity of water in the cell of a microscope cell-slide in such a way as to be shut off from an air supply. Under these conditions it would seem that accessory organs, if present, would be brought into play in order to obtain air from the water. No attempts to use the retractile processes were noted.

Closed spiracles.—One more simple test will now be described. Several larvæ were removed from water, and the tips of their

breathing tubes dipped in melted paraffin in order to close the spiracles. These larvæ were then placed in water again and observed at intervals for four hours. A check lot of untreated larvæ was also observed during the same time. The larvæ with spiracles closed could not be observed to perform differently from those with spiracles in normal condition. No larvæ of either lot attempted to extrude the retractile processes.

Summary.

1. The larva of *Eristalis arbustorum* L. obtains its air supply normally through the posterior pair of spiracles which are located at the tip of the tail-like breathing tube.

2. The anterior stigmatic horns function as spiracles when necessity demands; therefore the larva has the amphipneustic type of respiratory system.

3. In addition to the two pairs of functional spiracles there are eight pairs of atrophied spiracles in evidence.

4. The two main longitudinal tracheal trunks are greatly enlarged throughout much of their length. The enlargements have taenidia in their walls, and consequently are not true air sacs.

5. In the breathing process exhalation takes place by a collapsing and shortening of the main tracheal trunks. The muscles or other apparatus which initiate this activity were not observed.

6. Under the conditions of the tests, the rate of respiration varied between twelve and thirty exhalations per minute.

7. Several tests designed to induce larvæ to use the retractile, finger-like, anal processes as tracheal gills gave negative results, and no evidence was obtained in support of the theory that this insect has both open and closed respiratory systems.

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. *Eristalis arbustorum* larva, side view, showing tail-like breathing tube and retractile processes extruded from anus.

Fig. 2. Tip of breathing tube showing the feather-like setæ.

Fig. 3. End view of tip of breathing tube showing openings and feather-like setæ.

Fig. 4. (*a*) One of anterior stigmatic horns showing tooth-like lobes. (*b*) Stigmatic felt from spiracle opening of the stigmatic horn.

Fig. 5. Diagrammatic drawing of larva to show position of main tracheal trunks. (*a*) Anterior section of main tracheal trunk showing its bent position. (*p*) Posterior section of main tracheal trunk showing its bent position.

Fig. 6. Tracheation of ventral body-wall of anterior end of larva. (*I*, *II*, and *III*) Attachments of ventral tracheæ to main longitudinal trunks. (*atc*) Anterior commissure. (*c'*) Accessory tracheal branch. (*Imb*) Imaginal bud attachment to body-wall. (*j*) Anterior spiracular connective. (*n*) Sternal trachea. (*o*) Ganglionic trachea. (*o'*) Accessory ganglionic trachea. (*p'*) Leg trachea.

Fig. 7. Retractile processes as they appear while extruded from anal opening, (ventral aspect). (*an*) Anus. (*ba*) Basal part. (*fi*) Finger-like process. (*ti*) Smaller retractile tip of finger-like process.

Fig. 8. Diagrammatic drawing of enlarged portion of a main tracheal trunk in inflated condition showing position of taenidia.

Fig. 9. Same as Fig. 8, but showing position of taenidia at termination of an expiration.

Fig. 10. Hypothetical primitive respiratory unit. (*sp*) Spiracle. (*spp*) Spiracular pit. (*spt*) Spiracular trunk. (*st*) Sternal trachea. (*lt*) Leg trachea. (*pt*) Pleural trachea. (*gt*) Ganglionic trachea. (*asc*) Anterior spiracular connective. (*adc*) Anterior dorsal connective. (*pdc*) Posterior dorsal connective. (*alt*) Anterior latero-tergal trachea. (*plt*) Posterior latero-tergal trachea. (*tadc*) Tip of anterior dorsal connective. (*tpdc*) Tip of posterior dorsal connective.

PLATE II.

Dorsal view of *Eristalis arbustorum* larva showing especially the tracheation of the dorsal body-wall.

(*I-X*) Attachments of spiracular trunks to main longitudinal trunks.

(*1–8*) Dorsal connectives.
(*A*) Minor visceral trachea.
(*B*) Main visceral trachea.
(*C*) Spiracular trunk.
(*as*) Accessory trachea from anterior tracheal commissure.
(*Atc*) Anterior commissure.
(*e*) Fat-body trachea.
(*f*) Posterior branch of dorsal connective.
(*fla*) Tracheæ to retractile processes.
(*g*) Anterior branch of dorsal connective.
(*h*) Minor commissure.
(*j*) Anterior spiracular connective joined with leg trachea to form lateral trunk.
(*k*) Atrophied spiracle.
(*m*) Posterior latero-tergal trachea.
(*n*) Sternal trachea.
(*o*) Ganglionic trachea.
(*p*) Leg trachea.
(*Ptc*) Posterior commissure.
(*s*) Anterior latero-tergal trachea.

PLATE III.

Part of internal anatomy of *Eristalis arbustorum* larva showing especially the tracheation of alimentary canal, salivary glands, Malpighian tubes, fat-body, and part of tracheation of nervous system. Ventral view of right main tracheal trunk.

(*I-X*) Attachments of spiracular trunks to main longitudinal trunks.

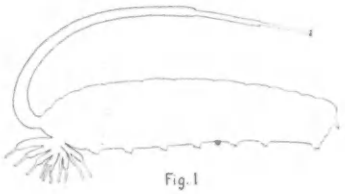
(*A*) Minor visceral trachea.
(*A'*) Minor trachea to breathing tube.
(*a*) Branch of accessory trachea to ganglionic mass.
(*B*) Main visceral trachea.
(*Ba*) Accessory visceral trachea.
(*C*) Spiracular trunk.
(*At*) Head atruim.
(*Ph*) Pharynx.
(*Sg*) Salivary gland.
(*Oe*) Oesophagus.
(*Br*) Brain.
(*Soe*) Ganglionic mass.
(*Mlg*) Gland of Malpighian tube.
(*Gc*) Gastric caecum.
(*Pr*) Proventriculus.
(*St*) Mid-intestine (stomach).
(*Fb*) Fat-body.
(*Ml*) Malpighian tubes.
(*Hi*) Hind intestine.

PLATE IV.

Lateral view of *Eristalis arbustorum* larva in distended condition showing part of respiratory system.

(I-X) Attachments of spiracular trunks to main longitudinal trunks.

(*1–8*) Dorsal connectives.
(*C*) Spiracular trunk.
(*j*) Anterior spiracular connective.
(*k*) Atrophied spiracle.
(*m*) Posterior latero-tergal trachea.
(*n*) Sternal trachea.
(*o*) Ganglionic trachea.
(*p*) Leg trachea.
(*s*) Anterior latero-tergal trachea.
(*t*) Spiracular trunk from spiracle at tip of breathing tube.



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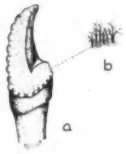

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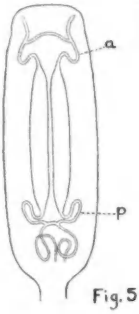

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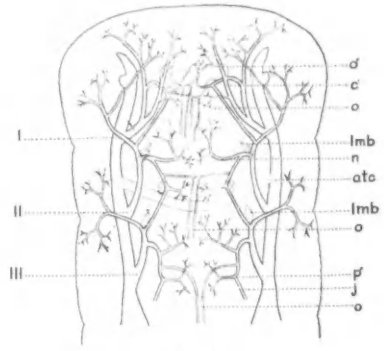

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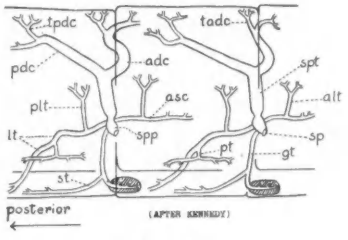

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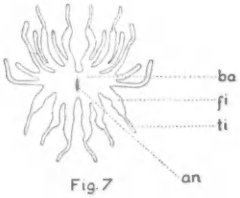

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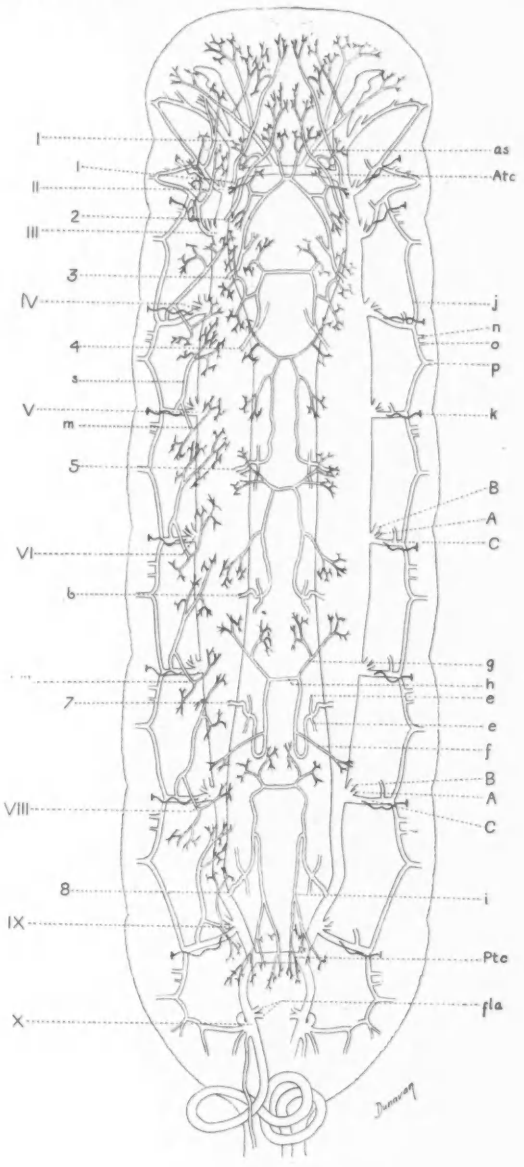
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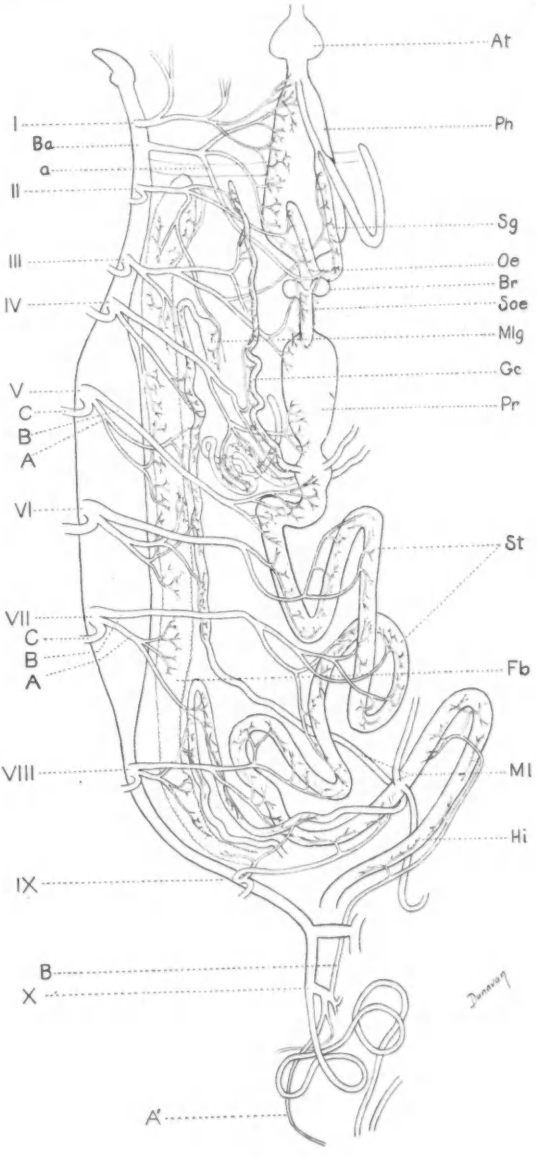
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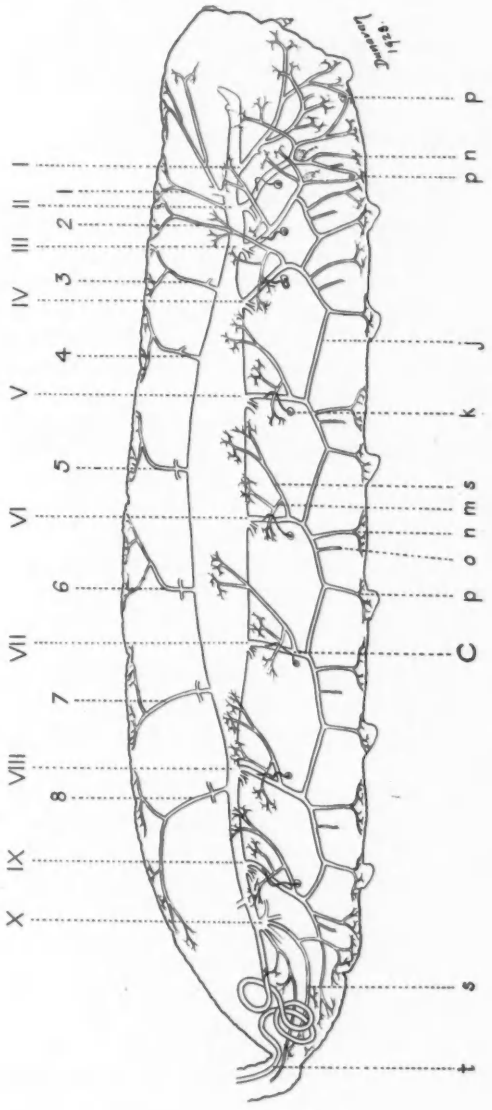
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SOME BEES OF THE GROUP TRACHANDRENA, ROBERTSON (HYMENOPTERA: ANDRENIDAE).

T. D. A. Cockerell

Robertson, in 1902, undertook to break up *Andrena*, as then understood, into six genera represented in the Illinois fauna; of these *Trachandrena* stood out as a very distinct group, and one would like to accept it as a full genus, but for the difficulty of limiting it accurately when dealing with the species of the Holarctic Region. Viereck, in 1924, recognized Andrena as a genus including eleven subgenera, dividing Robertson's *Trachandrena* into two parts, one of which he called *Scrapteropsis*. While this treatment did not seem very illuminating, it was probably a move in the right direction, and no doubt we shall have to accept a large number of subgenera, convenient for the grouping of the species, but not to be raised to generic status.

The tables of Robertson (Trans. Amer. Ent. Soc. XXVIII, p. 189) and Viereck (Guide to Insects of Connecticut, Part III) make the recognition of the species of the Eastern United States fairly easy. In the west there are doubtless many species still to be described, and such tables as have been published by Viereck and by myself represent only fragments of the fauna.

There are some outstanding questions which it is worth while to discuss:

(1) The western group of *A. mellea* Cress., *A. prunorum* Ckll., *A. argemonis* Ckll. stands near Trachandrena, but is really distinct. The male of *A. prunorum* has a yellow clypeus. These bees are extremely similar to some which inhabit the drier parts of Asia, as I hope to show in detail later on.

(2) *Andrena mariæ* Rob. extends west into Colorado, but in the Rocky Mountains gives off segregates, *A. sphecodina* Casad. & Ckll. (New Mexico), and *A. martialis* Vier. & Ckll. (Colorado), which may perhaps best be regarded as of subspecific rank.

(3) *A. ceanothi* Vier. and *A. heraclei* Rob. are very close, but distinguishable.

(4) *A. multiplicatiformis* Vier. is represented in the extreme northwest by the earlier described *A. grandior* Ckll., having the first tergite more strongly punctured apically.

(5) *A. imitatrix* Cres., based on three females from Texas, appears to include within specific limits the forms called *texana* Cress. (male from same lot as *imitatrix*), *profunda* Vier., and *claytoniæ* Rob. In the male, it seems that *claytoniæ* is smaller than *profunda*, with clear amber stigma. In the female, some placed with *claytoniæ* have an evident median raised line or keel on clypeus, and some lack this. In his original description Robertson said, "clypeus often with a median impunctate line." It may be suspected that there is in reality a little group of closely allied species, but if so, the matter has yet to be elucidated.

(6) *A. hippotes* Rob. is represented in Colorado by *A. perforatella* Ckll., smaller, with the hair marks at sides of abdomen very pure white. I think *perforatella* cannot rank as more than a subspecies.

(7) *A. forbesii* Rob. has been held to include *A. weedi* Viereck. On comparing specimens I find them closely allied but distinct. Thus in *A. forbesii* the raised portion of the second tergite is quite closely and evenly punctured all over, while in *weedi* this part is polished, with weak indefinite punctures. My *A. weedi* are from Waldoboro, Maine (*Lovell*).

These insects have been carefully collected in only a few places. The subject is now advanced sufficiently to make the study attractive and not too difficult. The flower visiting habits and times of flight have been set forth for Illinois in great detail by Robertson, and for Wisconsin by Graenicher. The tendency to form local races or subspecies, already evident, should be further investigated, and we should find out whether these differences are associated with peculiarities of climate or differences in the flower, visited, or both.

Andrena (Trachandrena) rodecki sp. n.

♀ Length about 9.5 mm., anterior wing, 7.5 mm.; black, robust, the head and thorax with rather abundant erect pale grey hair, ochreous on vertex, and tinged with ochreous on scutellum and more or less on posterior part of mesothorax; malar space very short; mandibles black; process of labrum large, broadly truncate, the sides sloping rapidly; facial quadrangle about square; clypeus convex, hairy all over, coarsely rugose, punctate, the apical middle shining, no ridge or smooth

line; antennæ black, third joint densely pitted, not as long as next two combined; facial foveæ broad, pale, with a faint ochreous tint, extending below level of antennæ, separated by a shining line from eye; mesothorax and scutellum dullish, coarsely and densely punctured, the mesothorax minutely tessellate between the punctures; area of metathorax strongly irregularly plicate, broadly truncate behind; mesopleura dull, rugoso punctate; tegulæ reddish black, strongly hairy; wings greyish hyaline, dusky at apex; stigma moderate, bright ferruginous, with broad darker margin; nervures dilute fuscous; basal nervure meeting nervulus; second cubital cell rather broad, receiving recurrent nervure a little beyond middle; legs black, with pale hair, hind tibiæ and tarsi ferruginous; tibial scopa pale, shining white in an oblique light; abdomen convex, shining, finely but very evidently punctured, first tergite closely punctured, second depressed in middle a little more than half; tergites 2 to 4 with lateral white hair bands on fourth not very broadly interrupted; apical tuft bright clear orange ferruginous.

Geneva Park, Boulder, Colorado, May 14, 1929. (Hugo Rodeck). Closely related to *A. heraclei* Rob. (specimen from Algonquin, Ill., compared), but tegulæ dark, mesothorax much duller and more closely punctured, hind margins of tergites black. The large separated punctures on middle of clypeus readily separate it from *A. spiraeana* Rob.

Andrena (Trachandrena) spiraeana Robertson.

Boulder, Colorado, June, 1929. (Norma LeVeque). New to Colorado.

Andrena (Trachandrena) forbesii Robertson.

Boulder, Colorado, May 24. (Maxy Pope). New to Colorado.

Andrena (Trachandrena) multiplicata Cockerell.

Boulder, Colorado, June 6, 1919. (Doris G. Roberts). New to Colorado.

Of the thirteen species of Trachandrena taken at Boulder, six are identical with species taken by Robertson at Carlinville, Illinois. Carlinville has eleven species. In Milwaukee County, Wisconsin, Graenicher took eight species of *Trachandrena*, of which five were common to Carlinville, and four occur at Boulder. One of the Wisconsin species (*A. multiplicata*) occurs at Boulder, but not at Carlinville.

Andrena (Trachandrena) obscura Robertson.

♀ Length about 10 mm., anterior wing, 7.8; black, robust, the head and thorax with rather thin dull white hair, clear white and conspicuous at sides of face and of metathorax; malar space linear; mandibles black; process of labrum broadly truncate; facial quadrangle about square; clypeus shining, but closely and strongly punctate, with a more or less evident smooth middle line; facial foveæ rather broad, their pubescence white, foveæ extending below level of antennæ, but about middle is a broad shining space between fovea and eye; vertex shining, with scattered punctures; antennæ with fourth joint not quite as long as next two combined; flagellum very dusky reddish beneath, its basal joints rugose; mesothorax and scutellum shining, but not highly polished, with large scattered punctures; area of metathorax strongly plicate, the sides adjacent very coarsely reticulate, just above the white fringe; mesopleura coarsely sculptured; tegulæ large, nearly black, shining dark rufous posteriorly; wings hyaline, slightly reddish, stigma and nervures dark reddish brown; basal nervure meeting nervulus; second cubital cell receiving recurrent nervure slightly beyond middle; legs black, spurs ferruginous; tibial scopa white; abdomen shining, finely punctured, weakly and rather sparsely on first tergite; second tergite in middle depressed more than half; tergites 2 to 4 with clear white hair bands at sides only; apical tuft dilute chocolate.

Falls Church, Virginia, July 4 (Cockerell). Resembles *A. spiraeana* Rob., *A. ceanothi* Vier., and *A. multiplicatiformis* Vier., but quite distinct. I had decided to describe it as a new species, as it seems different from my only specimen of *A. obscura* Rob., unfortunately a male, determined by Viereck. The matter was rendered more obscure from the fact that Robertson introduced his *obscura* (1902) in a few words in a table only, and did not know the male. I discover from Robertson's recent book that the type of *A. obscura* was from flowers of Pycnanthemum, a plant which begins to bloom at Carlinville June 19. Moreover, Viereck records *A. obscura* at Colebrook, Conn., July 21. There are very few Trachandrena flying as late as July, and putting together all the fragments of evidence, I am now convinced that my supposed new species is in fact *A. obscura*, which may I hope be rescued from its obscurity by a recognizable description.

Andrena (Trachandrena) indianensis sp. n.

♀ Length about 10.5 mm.; black, unusually slender, hair of head and thorax thin and dull white, not at all ochreous; malar space obsolete; mandibles red at apex; process of labrum large, truncate apically, with very gradually sloping sides; head very broad, facial quadrangle broader

than long; clypeus shining, strongly but not very densely punctured, somewhat flattened and more sparsely punctured in middle; facial foveæ dull white, very broad above, almost reaching lateral ocelli, only little narrowing below to end below level of antennæ, and separated from eye by a shining line; front rugose, vertex dull; antennæ black, with third joint shorter than next two combined; hair of thorax above thin and outstanding (not at all velvety); mesothorax dullish, with rather close small but distinct punctures, between which the surface is minutely tessellate; scutellum shining, not densely punctured; area of metathorax dull and poorly defined, very coarsely and irregularly rugosoplicate; mesopleura dull and densely rugulose; tegulæ anteriorly black, posteriorly shining reddish; wings hyaline, faintly reddish; stigma large, uniform dusky red; nervures rather dilute fuscous; basal nervure falling short of nervulus; second cubital cell large and broad, receiving recurrent nervure at middle; legs black, the tarsi brownish apically; scopa of hind tibia loose and white, the hairs on outer face simple, strongly bent (the pollen collected is very pale, and does not belong to the Compositæ); abdomen broad and flattened, shining, finely but distinctly punctured, without bands, the apical tuft light greyish brown; first tergite distinctly punctured all over; second depressed less than half, the edge of the depression straight; some thin pale hair placed obliquely at sides of tergites 2 to 4.

4 ♀ ♀, Bloomington, Indiana, (Ellis). Rather like *A. crataegi* Rob., but conspicuously less robust, with hair on inner side of hind basitarsi white, and sculpture of head and thorax different.

BOOK NOTICE.

A MANUAL OF EXTERNAL PARASITES, by Henry Ellsworth Ewing. Charles C. Thomas, publisher.

This book includes keys to most of the genera in the groups that are externally parasitic, limited to the mites, ticks, biting lice, sucking lice and fleas. More particular attention has been given to those which have the greater economic importance and the work is intended as a hand-book for students, veterinarians and medical men interested in these forms. The illustrations, which are quite profuse are, many of them, from the accurate drawings of the author and will be of great service in recognizing the characters used in the keys, as also for certain of the species. While not intended as a treatise on the control of parasites, but rather as a means of recognition for them, it includes in many instances the recognized methods of treatment. A point which should have the attention of taxonomists is that a number of new genera are described and the author justifies their inclusion in the Manual for the reason that they are associated with the keys to the groups to which they belong. On this account it is the more important that the work be fully noted in bibliographical records. The author had the distinct advantage of access to all the important collections in these groups which are under his care in the National Museum. H. O.

A NEW VELIA FROM ARIZONA WITH NOTES ON OTHER SPECIES

(HEMIPTERA - VELIIDAE)

H. B. HUNGERFORD,
Department of Entomology, University of Kansas.

For the past three summers Entomological expeditions from the University of Kansas under the field direction of Doctor R. H. Beamer have been made into the southwestern part of the United States. Besides making rich additions to the collections made by Dr. Francis Huntington Snow many years ago, Doctor Beamer and his assistants have added many undescribed insects. One of them is described below:

Velia beameri species new

Size: Length 6.6 mm. to 7 mm.; width across head 1.2 mm.; width across front margin of prothorax 1.7 mm.; greatest width 2.8 mm.

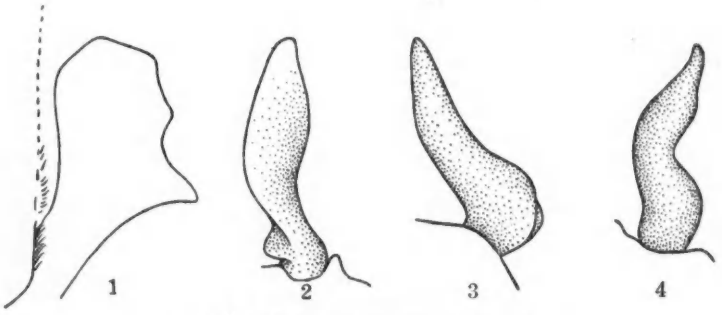
Color: Chocolate brown with two silvery triangular patches on pronotum, silvery transverse bands on segmental lines of the connexivum, slender median streak of silver on dorsum of first two abdominal segments, silvery hairs on last four abdominal segments arranged in a more or less definite inverted U; venter brown, frosted, with silvery patches at bases of acetabula and on sides of abdomen; Antennæ brown; legs contrastingly banded—pale horn and dark brown, coxæ, trochanters and basal half of femora pale horn with slight infuscation on rear side of trochanters and bases of femora of front and middle legs. Outer half of femora and distal segments dark brown banded with pale horn as follows: A pale band in middle of dark outer half of femora—a small faint one at base of tibiæ, a broad one near the middle of the tibiæ and another covering most of the second tarsal segments of the middle and hind legs.

Structural characteristics: A robust species with the anterior part of pronotum distinctly wider than the head. Rear margin of pronotum (apterous form) broadly rounded, semicircular. Pronotum pitted, calli elevated, faint median longitudinal carina on pronotum. Antennæ formula as follows: 1st:2nd:3rd:4th::9:5:5.5:5. (In the third segment I have counted the short intersegmental segment). Interocular space slightly wider than an eye. Body and limbs covered with hairs about as in *Velia brachialis*—Stal. Genital claspers of the male something like those of *Velia brachialis*—Stal.

Described from a male and female from Santa Rita Mountains, Arizona. Taken by Doctor R. H. Beamer July 24, 1927.

Holotype and allotype in the Entomological collection of the University of Kansas.

Comparative notes: This species I had determined to be *Velia annulipes* Champion but in comparing it with the type in the British museum I found it to be slightly larger, of different color from Champion's species and to possess a male genital clasper of decidedly different shape. Champion's male type is reddish brown in color with nearly black patches on the anterio-lateral angles of the prothorax. The head is broader than in my species and body not as broad. The antennæ have lost the last two segments but the formula for the basal segments is: 1st; 2nd::3.25:2 and the basal segment is longer, straighter and more slender than in the female specimen of my species



LEFT MALE GENITAL CLASPERS OF SOME VELIA.
1. *Velia Annulipes* Champ.
2. *Velia conata* Hungerford.
3. *Velia beameri* Hungerford.
4. *Velia brachialis* Stal.

with which I compared it. The hind femora of Champion's type are about the same thickness with only about ten slightly thicker and a little more prominent spines. The shoulders of the type are raised and the anterior central elevation of the pronotum is crescent shaped, smoother and flatter than in my species and continued behind by a broad carinal base. In the Museum at Vienna I found two specimens marked "Cotypes" "Mexico Coll. Signoret" one labeled "Sp. fig. by Champ. = ♂." In this male which is wingless and considerably smaller than my species, the first segment of the antenna is long and thin and appears as long as pronotum (this is not true of the female

however). In the male, what appears to be the fifth ventral abdominal segment is produced behind beyond the rear margin of the next segment. The middle tarsal segment of middle tarsus is longer than terminal (using short side of terminal) otherwise they are subequal.

Velia beameri species new is larger and different shape from *Velia brachialis* Stal., the type of which I have seen in the Museum at Stockholm. *Velia brachialis* Stal. was described from Rio Janeiro but I have compared with the type some specimens from Colorado County, Texas, taken by Mrs. Grace Wiley and they are identical.

The Velia of the Western Hemisphere appear to fall into several groups. One group is so distinct from the species first described in the genus that I recently separated it under the subgeneric name Stridulivelia. Other natural groupings are:

II. The *Velia stagnalis* Burm, group which includes also *Velia watsoni* Drake and *Velia virgata* White.*

III. The *Velia basalis* Spinola group for which Breddin proposed the genus name Paravelia but to which his own species, *Paravelia boliviana* Breddin does not, I believe, belong.

IV. The *Velia inveruglas* Kirkaldy group which resembles more than any of the others, the European Velias. Through the very great kindness of Dr. Alfredo Borelli I was permitted to examine the type of *Velia inveruglas* Kirkaldy in the Museum of Zoology of the University of Turino. I can find no structural characteristics to distinguish *Velia osborniana* Kirkaldy, (new name for *Velia brunnea* Osborn), from it. *Velia albotrimaculata* Kirkaldy, the female type of which I studied in the Royal Museum at Brussels, belongs in this group and perhaps also a smaller but beautiful species with an orange red head and pronotum and three white spots on black wings which I described in the Museum at Stockholm under the name of *Velia helenæ*.

V. The *Velia brachialis* Stal. group which besides *Velia annulipes* Champ. and *Velia beameri* includes *Velia conata* Hungerford, an interesting and characteristic species that is a little smaller than *Velia brachialis* Stal, has somewhat the same general appearance but is distinguished by a conate elevation on the pronotum.

*I have examined the type of White's *Velia vivida* and find it to be a Rhagovelia.

TWO NEW SPECIES OF ERIOCOCCUS FROM MISSISSIPPI.

(Homoptera: Coccoidea).*

With two plates and eleven figures.

GLADYS HOKE LOBDELL,
A. & M. College, Mississippi.

Descriptions of two species of the genus *Eriococcus* are presented at this time for publication in anticipation of the use of the names in a forthcoming paper on some scale insects of Mississippi.

Mr. E. E. Green (Coccidæ of Ceylon, Pt. V, page 345, 1922) gives the group sub-family rank as the *Eriococcinæ*. He says, however, "I have treated this group as a separate family." As members of the genus *Kermes* are recognized as being of the Eriococcine type and are placed in the subfamily, or family as it is here designated, with *Eriococcus*, it seems advisable to use the name *Kermesidæ* in preference to *Eriococcidæ* for this group. *Eriococcus* was first used as the name of a genus by Targionia in 1869. The genus *Kermes* is credited to Boitart, Manual d'Entomologie, 1828, and, although I have not had the privilege of examining the publication, the name is generally accepted for the genus, apparently having been substituted for the term *Chermes* which had been previously used for an aphid by Linnaeus.

Kermesidæ.

This group, which I am treating as a family and calling the *Kermesidæ*, is characterized by the presence of conspicuously prominent anal lobes, at least during the larval stage (as in *Kermes*), which persist in some genera in the adult stage (as in *Eriococcus*); antennæ with not more than seven segments, the distal segment short, not of the Pseudococcine type; tarsus relatively long, usually as long as or longer than the tibia; the anal ring bearing setæ in at least the larval stage of development (as in *Kermes*), which frequently persist in the adult stage (as in *Eriococcus*).

*Contribution from the Entomology Laboratory of the Mississippi Agricultural Experiment Station and the State Plant Board of Mississippi.

Eriococcus pilosus, new species.

Sac of Female.—Female enclosed in a tough yellow-white felted sac, 3.5 mm. long, outer part of case of loose woolly fibers; dead insect, deep red color, turning lighter and brighter in KOH and easily losing its color; KOH solution colored for short time around specimen; dried body of insect without waxy powder; spines of dorsal surface quite noticeable under low power binocular when in KOH.

Adult Female.—Body of specimens examined 2 to 2.64 mm. long, .6 to 1.5 mm. broad; elongated, tapering towards ends; derm membranous except portions of anal lobes; antennæ seven-segmented, basal segment slightly broader than long, much shorter on lateral aspect than on mesal, as long as or slightly longer than fifth and sixth segments, which are subequal, third and fourth longest, subequal, fourth often with indication of pseudosegmentation, distal segment bearing about nine to eleven long stiff setæ, third segment apparently without setæ, others usually with two or more setæ on distal half; legs tapering, coxæ large, longer than broad, each trochanter bearing a stiff tapering seta, slightly longer than coxa itself or longest ventral thoracic setæ, femur broadest through middle, tibia and tarsus subequal in length, very slender, claw with small denticle, ungal digitules slender, tarsal digitules similar but larger, both dilated at distal end, each hind coxa with about 25 to 35 large pores on posterior ventral surface; spiracles small, only slightly narrower in center than at ends; tentorium compact, heavily chitinized, rostrum two-segmented; dorsal surface with a number of long tubular ducts, each opening to surface through pore with non-chitinized rim, usually difficult to detect, distal or ental end of larger part of duct cup-shaped and chitinized, continuing as a smaller duct from one edge of cup, this smaller and distal portion of duct very difficult to see in most specimens; numerous minute ducts (?) with chitinized rims on basal portions; ventral surface with ducts of same type but smaller; dorsal surface with numerous rather long and slender spines of two sizes, most numerous on head and thorax, apparently in three rows on each side, mesal rows in close proximity and giving the appearance of one double row, marginal row extending to anal lobe, mesal row extending on to sixth abdominal segment, two median spines on fourth, fifth, and sixth abdominal segments very much reduced and inconspicuous, on some specimens lateral row on these segments represented by a single inconspicuous spine, this row on head and thorax apparently usually consisting of two large spines and a small one transversely arranged, limits of rows not always readily discernible; ventral surface with a few long, slender setæ especially on meson, ducts of same type as those of dorsum, but smaller, multilocular pores and minute filiform projections on ventral surface of abdomen, most numerous in region of vulva; anal lobes long, slightly chitinized, bearing on dorsal surface three spines, a small one near base of lobe on mesal margin and two long ones near meson of lobe about size of large marginal spines; ventral surface of lobes with two slender setæ slightly longer than those on dorsal surface; a similar larger seta near cephalic end of anal ring and three or four

pairs on segments cephalad and caudad of vulva; eight anal ring setæ, about two-fifths as long as anal lobe setae.

Host—Thistle, (*Cirsium* sp.) on under surface of dead leaves. Locality.—A. & M. College, Mississippi: February 14, 1927, Collected by Dr. M. R. Smith.

This species is probably more similar to *tinsleyi* Ckll., 1898, than to other species, though it resembles *stanfordianus* Ferris, 1920, in the definite arrangement of the dorsal spines.

Holotype in the Coccid collection of the Mississippi State Plant Board.

Eriococcus smithi, new species.

Sac of female: 2.2 to 2.9 mm. long, .6 to 1.1 mm. broad, closely felted, tough, light brown color, flattened dorsally, dorso-lateral edges prominent, very convex ventrally, posterior margin with small dorsal opening; frequently unsymmetrical due to crowding, posterior end of one overlapping anterior end of the following one, these usually arranged along midrib on dorsal surface of leaf.

Sac of male: Usually 1.1 mm. long, .4 mm. broad; dirty white color, closely felted, but less so than in female, comparatively brittle, cylindrical or subcylindrical, ends bluntly rounded, posterior slightly flattened and thin; arranged on dorsal surface of leaf.

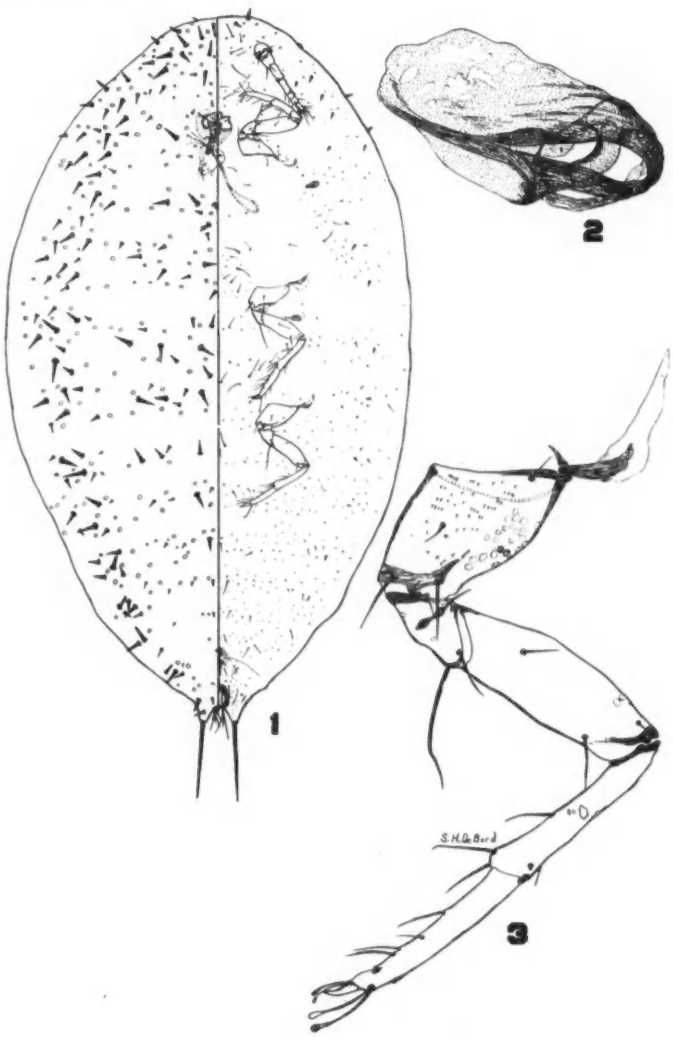
Adult Female.—Body mounted on slide 1.55 mm. to 2.07 mm. long, .59 mm. to .85 mm. broad; derm membranous except anal lobes; antennæ usually seven-segmented, occasionally an antenna with five or six segments; legs long and slender, hind coxæ with a few irregular clear areas varying in size, tibiæ from three-fifths to four-fifths as long as tarsi, digitules longer than claws, claws long and slender; spiracles medium small and broad; tentorium as broad as long, rostrum as broad as long, about seven-eighths as long as tentorium; body with numerous tubular ducts, only the inside of cup chitinized, setæ on dorsal and ventral surface arranged in transverse rows, dorsal shorter than ventral; a few multilocular disc pores, most numerous in region of spiracles and vulva; margin with long chitinized spines, ends truncate; anal lobes chitinized, outer, dorsal edge with one and inner with two spines of marginal type, ventral side with a short, a median, and a long apical seta, anal ring with eight setæ about one-half as long as anal lobe setæ.

Host.—Broom sedge (*Andropogon virginicus* L.). Locality: Meridian, Mississippi: November 14, 1927. Collected by Dr. M. R. Smith. Attended by Argentine ants (*Iridomyrmex humilis* Mayr.).

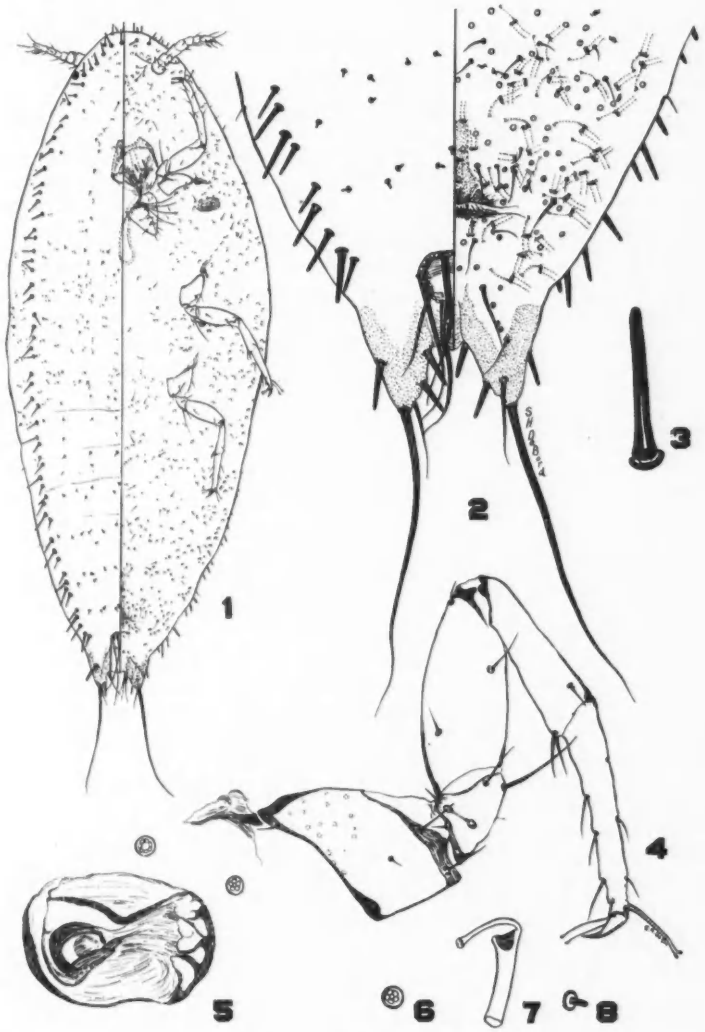
The sacs of the males and females are usually (?) segregated on different blades of grass, but occasionally male sacs are found associated with those of the females.

Dr. Morrison says, "This insect is undoubtedly very closely related to *Eriococcus kemptoni*, differing only in having the spines somewhat stouter and more blunt tipped at the apices and in having the large marginal spines suppressed in the middle part of the body."

Holotype in the Coccid collection of the Mississippi State Plant Board. Paratypes in the Coccid collection of the United States National Museum, Washington, D. C., and in the collection of the Mississippi State Plant Board.



Eriococcus pilosus, new species.
1, Adult female, × 58; 2, Anterior spiracle, × 706; 3, Hind leg, × 182.



Eriococcus smithi, new species.

1, Adult female, × 64; 2, Posterior end of abdomen, × 184; 3, Marginal spine, × 683; 4, Hind leg, × 273; 5, Posterior spiracle, × 683; 6, Pore, × 683; 7, Duct, × 683; 8, Dorsal body seta, × 683.

NEW SPECIES OF CRANE FLIES FROM SOUTH AMERICA. PART III.*†

(Family Tipulidæ, Order Diptera).

CHARLES P. ALEXANDER,
Amherst, Mass.

The great majority of the species discussed at this time are from *Argentina*, collected by Messrs. Bruch, Shannon and Weiser; *Paraguay*, collected by Schade; and *Ecuador*, collected by Tate. The interesting *Tipula* is from *Colombia* and was included in extensive collections of crane-flies belonging to the British Museum, kindly loaned to me for study by Mr. Edwards. Except where stated to the contrary, the types of the new species are preserved in my collection.

Tipula Linnæus.

Tipula colombicola sp. n.

Belongs to the *macrosterna* group; nearly allied to *trinidadensis* Alexander; antennæ more elongate, nearly one-half the length of the body in male; three complete thoracic stripes; ninth tergite of male hypopygium with a quadrate median notch.

Male. Length about 13 mm.; wing, 12 mm.; antenna about 6 mm.

Frontal prolongation of head dark brown dorsally, heavily pruinose, the remainder light yellow; palpi chiefly obscure yellow. Antennæ more elongate than in *trinidadensis*, the scape light yellow; first flagellar segment black, the distal half yellow; remaining segments black, their extreme tips light yellow, the outer segments more uniformly darkened. Head obscure yellow, the center of the vertex conspicuously dark brown.

Mesonotal praescutum yellow, with three conspicuous shiny dark brown stripes; scutal lobes yellow, each variegated with two lighter brown areas; postnotum whitish pruinose. Pleura heavily white pruinose, the dorso-pleural membrane light yellow, dusky before the wing-root; a blackish spot on anepisternum. Halteres yellow, the base of the knobs darker. Legs with the coxæ pale, weakly pruinose; femora yellow, the tips very narrowly but conspicuously dark brown;

*Contribution from the Department of Entomology, Massachusetts Agricultural College.

†The preceding parts under this general title were published in these ANNALS in 1926 (XIX: 378-394), and 1928 (XXI: 623-641).

tibiæ brownish yellow, the tips very narrowly infuscated; tarsi elongate, pale brown, gradually passing to brownish black. Wings yellowish gray, the prearcular and costal regions bright yellow; stigma pale brown, a little darker than the ground-color; veins yellowish brown. Venation about as in other members of the *macrosterna* group.

Abdominal tergites reddish yellow, the intermediate segments with a shiny black median triangle; segments seven and eight black, to produce a subterminal ring; hypopygium large, fulvous-yellow. Male hypopygium with the median incision of the ninth tergite relatively deep and narrow, the lateral lobes directed caudad and mesad, blackened. Dististyles very complicated in structure; dorsal submedian lobe that is chisel-shaped in *trinidadensis* is here more acutely bispinous, the ventral spine longer and more conspicuous; the outermost style or blade is extended laterad into a conspicuous spine.

HABITAT: Colombia. *Holotype*, ♂, Lake Sapatoza Region, Chiriguana District, August-September, 1924 (C. Allen). Type in the British Museum (Natural History) No. 1925–576.

Limonia Meigen.

Limonia (Limonia) catamarcana sp. n.

General coloration brownish gray; antennæ brownish black, the first segment yellow; knobs of halteres darkened; legs chiefly obscure yellow; wings whitish subhyaline, sparsely variegated with brown; a supernumerary crossvein in cell *Sc*, close to Sc_2; *m-cu* before the fork of *M;* male hypopygium with the rostral prolongation of the ventral dististyle very high and compressed, the two spines placed on the side near the ventral margin.

Male. Length about 5.5 mm.; wing, 6.5 mm.

Rostrum obscure yellow, the palpi darker. Antennæ with the basal segment yellow, the remainder brownish black; flagellar segments oval. Head chiefly brownish gray, the front and occiput more yellowish.

Pronotum dark medially, paling to yellow on the sides. Mesonotal praescutum brownish gray, darker medially, the humeral region more brightened; scutal lobes dark brown, the median region and scutellum pale yellow; postnotum dark, pruinose. Pleura variegated brown and yellow, the surface pruinose; dorso-pleural region paler. Halteres pale, the knobs darkened. Legs with the coxæ obscure yellow, the fore coxæ darker; trochanters yellow; remainder of legs obscure yellow, the tarsal segments passing into dark brown. Wings whitish subhyaline, the oval stigma darker brown; restricted dusky clouds at origin of *Rs*, along cord and outer end of cell *1st* M_2; veins dark. Venation: *Sc* ending some distance beyond origin of *Rs*, Sc_1 at about one-third the length of *Rs*, Sc_2 some distance from its tip; in both wings of

type and thus presumed to be normal, a supernumerary crossvein in cell *Sc* not far from Sc_2; *Rs* long, gently arcuated; cell *1st* M_2 long and narrow; *m-cu* about one-third to one-half its length before the fork of *M*.

Abdominal tergites brown, the incisures pale; sternites more uniformly yellow; hypopygium chiefly pale. Male hypopygium with the caudal margin of the tergite gently emarginate, the lobes low, each with from eight to ten setæ. Basistyle with the ventro-mesal lobe short and stout. Ventral dististyle relatively small, the rostral prolongation very high and compressed, the caudal margin gently rounded to the blunt tip; the usual two spines short, placed laterally on the face of the prolongation near the ventral margin. Dorsal dististyle curved to the long acute tip. Gonapophyses with the mesal apical lobe unusually short and inconspicuous, the margin of the notch microscopically serrulate.

HABITAT: Argentina. *Holotype*, ♂, Quebrada "Volcan," at Agua Amarilla, Catamarca, January 29, 1922 (V. Weiser).

Limonia catamarcana is quite distinct from other regional species of the subgenus. The entire aspect of the fly is that of a *Dicranomyia* rather than a *Limonia*, but from the venation the species must be referred to the latter subgenus. It seems very possible that the presence and position of the supernumerary crossvein in cell *Sc* is not constant for the species.

Limonia (Limonia) villaricæ sp. n.

General coloration dark brown; knobs of halteres darkened; legs chiefly obscure yellow; wings light brown, the stigma scarcely darker; Sc_1 ending about opposite two-fifths the length of *Rs; m-cu* longer than the distal section of Cu_1; male hypopygium with the rostral spines of the ventral dististyle two, subequal.

Male. Length about 4.6 mm.; wing, 5.3 mm.

Rostrum approximately one-half the remainder of the head, obscure yellow, darker apically; palpi brown. Antennæ with the scapal segments brown, a trifle paler than the brownish black flagellum; flagellar segments oval. Head brown, paler behind.

Mesonotum chiefly dark brown, the lateral margins of the praescutum and scutal lobes a little more reddish brown. Pleura similarly dark reddish brown. Halteres pale, the knobs dark brown. Legs with the coxæ brown, the trochanters obscure yellow; remainder of legs obscure yellow, only the last tarsal segment infuscated. Wings with a light brown tinge, the oval stigma scarcely darker, barely indicated; veins darker brown. Venation: Sc_1 ending about opposite two-fifths the length of *Rs*, Sc_2 not far from its tip; *Rs* arcuated to weakly angulated at origin; cell *1st* M_2 small, shorter than the veins beyond it;

m-cu a short distance before the fork of *M*, longer than the distal section of Cu_1.

Abdominal tergites dark brown, the sternites yellow; hypopygium brownish yellow. Male hypopygium with the tergite transverse, the caudal margin very gently emarginate, with numerous coarse setæ. Ventral dististyle fleshy, the rostral prolongation stout basally, narrowed to the obtuse tip; rostral spines two, placed on basal half of the prolongation, subequal and placed close together. Dorsal dististyle a relatively short curved rod, the tip suddenly narrowed into an acute spine. Gonapophyses with the mesal apical lobe broad, narrowed gradually to a small, slightly decurved point, the margin irregularly and microscopically roughened.

HABITAT: Paraguay. *Holotype*, ♂, Villarica, August 26, 1924 (F. Schade).

Limonia villaricæ is a small, insignificant species, characterised especially by its negative characters and structure of the male hypopygium.

Limonia (Dicranomyia) weiseriana sp. n.

General coloration gray; rostrum obscure yellow; wings whitish subhyaline, clouded with brown and gray; cell *1st* M_2 long and relatively narrow; male hypopygium with the spines of the rostral prolongation of the ventral dististyle long and straight, black, the outer about two-thirds of the inner; dorsal dististyle obtuse at apex.

Male. Length about 6–6.3 mm.; wing, 7–7.8 mm.

Female. Length about 6 mm.; wing, 8.2–8.3 mm.

Rostrum obscure yellow, the palpi black. Antennæ dark brown, the scapal segments somewhat paler; flagellar segments short-oval. Head gray, paler behind and beneath; anterior vertex broad.

Anterior lateral pretergites yellowish. Mesonotum chiefly gray, the praescutum with three darker gray stripes, the broader median stripe more distinct; median region of scutum and the scutellum paler, more yellowish gray. Pleura gray, with darker longitudinal areas on the anepisternum and sternopleurite. Halteres yellow, the knobs infuscated. Legs with the coxæ and trochanters yellow, the fore coxæ a trifle darker; femora yellow, the tips narrowly and weakly infumed; remainder of legs passing gradually into brown, the tips of the individual tarsal segments narrowly blackened. Wings whitish subhyaline, with a handsome brown and gray clouding; stigma brown, oval, more or less connected with a large cloud at the end of *Rs;* cord and outer end of cell *1st* M_2 more narrowly seamed with brown; extensive but paler gray washes on the median veins beyond the cord, as a seam at near midlength of the basal section of Cu_1, and the entire distal section of the same vein; similar extensive pale gray clouds on both anal veins; veins brownish yellow, darker in the clouded areas. Venation: *Sc*

short, Sc_1 ending before origin of *Rs*, Sc_2 a short distance from its tip; *Rs* relatively short and arcuated, about one-half longer than the more strongly arcuated basal section of R_{1+5}; cell *1st* M_2 relatively long and narrow; *m-cu* close to the fork of *M*.

Abdominal tergites obscure yellow, darker medially and caudally, the surface somewhat pruinose; sternites brown; hypopygium large, the ventral dististyle conspicuously orange-yellow. Male hypopygium with the tergite transverse, the caudal margin with a broad U-shaped emargination. Ventral dististyle very large and fleshy, the rostral prolongation stout, beyond the spines more narrowed, terminating in a chitinized point; rostral spines unusually long and conspicuous, black, nearly straight and directed strongly basad; outer spine about two-thirds the length of the inner, both exceeding in length the prolongation itself. Dorsal dististyle strongly curved, widened at near midlength, the tip obtuse. Gonapophyses with the mesal apical lobe long and slender, gently curved.

HABITAT: Argentina. *Holotype*, ♂, Quebrada "Volcan," at Agua Amarilla, Catamarca, January 29, 1922 (V. Weiser). *Allotopotype*, ♀. *Paratopotypes*, 5 ♂♂, with the types.

I dedicate this interesting crane-fly to the memory of the late Engineer Vladimir Weiser, to whom I am very greatly indebted for many Andean Tipulidæ, chiefly from Jujuy, Tucuman and Catamarca. Among the described regional species, *L. weiseriana* is most closely allied to *L.* (*D.*) *invalida* Alexander (Peru), differing especially in the more extensive pattern of the wings and the details of structure of the male hypopygium.

Limonia (Rhipidia) inæquipectinata sp. n.

Belongs to the *maculata* group; antennæ (♂) elongate, the flagellar segments tripectinate, one of the branches being very reduced, the other two long and slender; antennæ bicolorous; thoracic pleura gray with two narrow longitudinal brown stripes; wings gray with a sparse brown pattern; male hypopygium with the rostral prolongation of the ventral dististyle very long and slender, with two long curved spines placed far out toward the outer end; phallosome large and complicated in structure.

Male. Length about 5 mm.; wing, 6.6 mm.

Rostrum and palpi black. Antennæ (♂) elongate, if bent backward extending to some distance beyond the base of the abdomen; scape dark; basal enlargements of all segments and branches black, the elongate pedicel of the flagellar segments with the exception of the last white; first flagellar segment with a single basal branch that is about as

long as the pedicel; flagellar segments two to eleven with two very long basal branches, in addition to a small intermediate branch that is about as long as the basal enlargement; longest branches about two and one-half times the segment, clothed with a delicate pubescence; outer face of basal enlargements of segments with very long, conspicuous verticils that are subequal to the segments; terminal flagellar segment elongate, with verticils that are a little shorter than the segments. Head dark gray

Pronotum dark brown. Mesonotal praescutum light brown, with indications of three dark stripes near the suture; posterior sclerites of mesonotum chiefly dark-colored. Pleura gray with two narrow dark brown longitudinal stripes. Halteres yellow, the knobs dark brown. Legs with the coxæ yellow, their bases dark brown; trochanters light yellow; remainder of legs broken. Wings gray, with a sparse brown pattern; cell *C* infuscated; cell *Sc* variegated with brown; stigma oval, grayish brown; vague brown clouds at origin of *Rs*, confluent with a spot at end of *Sc*; a large area at fork of *Rs*, confluent with the stigma; pale seams along cord and outer end of cell *1st* M_2; brown seams in outer ends of cells R_2 and R_3; prearcular region white; veins dark brown, *Cu* chiefly yellow. Conspicuous macrotrichia on veins beyond cord. Venation: *Sc* relatively long, extending to about opposite midlength of *Rs*, Sc_2 at its tip; *Rs* angulated at origin; cell *1st* M_2 small; *m-cu* shortly before the fork of *M*.

Abdominal tergites obscure yellowish testaceous, the lateral margins narrowly, the caudal margins more broadly, infuscated; sternites yellow, the incisures darkened; outer segments darkened. Male hypopygium with the caudal margin of the tergite only gently emarginate. Basistyle with the ventro-mesal lobe long and slender, the apex a little expanded, provided with long conspicuous setæ; an additional series of powerful setæ along the margin. Ventral dististyle large and fleshy, with sparse inconspicuous setæ; rostral prolongation very long and conspicuous, the cephalic margin fimbriate with short dense yellow setæ; just before the apex with two long, slender, gently curved spines that are placed so close together as to appear almost as a single structure; immediately distad of the rostral prolongation, on the same face, the dististyle is produced into a pale conical fleshy lobe that is tipped with two or three elongate setæ. Dorsal dististyle a very long slender chitinized rod, strongly bent near midlength, the tip suddenly narrowed into a long straight spine. Gonapophyses pale, the mesal apical lobe elongate. Phallosome very large and complex in structure, including a pale fleshy central portion that is subtended by smaller fleshy lateral lobes.

HABITAT: Argentina. *Holotype*, ♂, Iguazu Falls, October 3–5, 1927, (R. & E. Shannon). Type in the United States National Museum.

The tripectination of the flagellar segments marks the extreme tendency, so far as at present known, in the tribe Limoniini.

Limonia (Rhipidia) bruchiana sp. n.

Belongs to the *maculata* group; allied to *subcostata* Alexander; antennæ (♂) with eleven long-branched segments; mesonotum chiefly light brown, the dorso-pleural region extensively blackened; halteres black, the base of stem and apex of knob conspicuously yellow; wings whitish subhyaline, with an extensive gray pattern, most evident as a series of five costal areas; axillary region extensively whitened; *m-cu* before fork of *M;* male hypopygium with the tergite small, transverse; rostral prolongation of ventral dististyle long, decurved, the two spines very small and stout.

Male. Length about 7 mm.; wing, 6.5 mm.; antenna, about 3.3 mm. Rostrum black, about one-half the length of the remainder of the head; palpi brownish black. Antennæ (♂) long and conspicuous, nearly half the length of the body, as shown by the measurements; scapal segments black; flagellar segments with the stems pale yellow, the branches black, the terminal segments dusky on outer half; antennæ 14-segmented, the formula being 2+11+1; all flagellar segments except the last long-bipectinate; branches of first flagellar segment subequal to the segment; of succeeding segments becoming gradually longer, the longest (about flagellar segments six to eight) more than twice the segment; flagellar segment eleven with the branches about one-half longer than the segment. Head dark gray; eyes (♂) above contiguous for a short distance.

Pronotum and anterior lateral pretergites restrictedly yellow. Mesonotal praescutum with the stripes light yellowish brown, the margins and interspaces narrowly margined with black; scutal lobes dark brown, the median area and scutellum more testaceous; postnotal mediotergite dark brown, paler caudally, the cephalo-lateral angles pale yellow, most of the surface in an oblique light slightly pruinose. Pleura brown, the dorsal region chiefly occupied by a conspicuous black longitudinal stripe. Halteres black, the base of the stem and apex of each knob conspicuously light yellow. Legs with the coxæ brownish yellow, darker basally; trochanters obscure yellow; femora brownish yellow, at or immediately before the tips with a dark brown ring; tibiæ brown; tarsi dark brown; posterior tarsi broken beyond the basitarsus, the latter brownish yellow; it is highly probable that the succeeding tarsal segments of the posterior legs are similarly yellow, as in other members of the *subcostata* subgroup. Wings whitish subhyaline, with an extensive gray or brownish gray pattern, somewhat heavier along the costal region where there are five major areas, the last being the stigma, these areas much more extensive than the interspaces; similar dark seams along the cord and outer end of cell *1st* M_2; basal axillary region conspicuously white; veins brown, the subcostal interspaces and vein Cu_1 more yellowish. Venation: Sc_1 ending about opposite three-fifths the length of *Rs*, Sc_2 at its tip; cell *1st* M_2 relatively

small, shorter than vein M_4 beyond it; *m-cu* about one-fourth its length before the fork of *M*.

Abdomen brown, the incisures somewhat darker. Male hypopygium with the tergite small, transverse, the caudal margin nearly straight, without setæ except two or three on lateral portions of sclerite. Basistyle with the ventro-mesal lobe large, strongly narrowed at apex, terminating in a powerful seta; mesal margin of basistyle with two powerful fasciculate setæ, the more cephalic one prolonged into a delicate hair-like point. Ventral dististyle with the rostral prolongation long, gently decurved and narrowed to the apex which bears a powerful terminal seta; rostral spines two, very short and stout, slightly separated, placed before midlength of the prolongation.

HABITAT: Argentina, Paraguay. *Holotype*, ♂, La Plata, Argentina, August 8, 1922, in room at light (Carlos Bruch). *Allotype*, ♀, Villarica, Paraguay, September, 1928, (F. Schade). *Paratypes*, 1 ♂, 1 ♀, with the allotype, September-November, 1928, (F. Schade).

I take great pleasure in naming this handsome *Rhipidia* in honor of the collector, my friend and colleague, Dr. Carlos Bruch. It is well-distinguished from *subcostata*, which seems certainly to be its nearest ally among the described species, by the coloration and details of structure.

Limonia (Rhipidia) pallatangæ sp. n.

Belongs to the *uniseriata* group; general coloration yellow, the mesonotal praescutum with a median dark brown stripe; antennæ black, the penultimate segment yellow, flagellar segments one to ten with a single branch; pleura with two narrow longitudinal brownish black stripes; halteres black, the apices of the knobs yellow; wings creamy-yellow, with a conspicuous brown and gray clouded pattern; abdomen yellow, the hypopygium concolorous; male hypopygium with the spines of the rostral prolongation of the ventral dististyle short and spike-like.

Male. Length about 6.5 mm.; wing, 8 mm.

Rostrum and palpi black, the former about one-half the length of the head. Antennæ black, the base of the first segment a little brighter, the penultimate segment light yellow; axes of the outer segments becoming paler, almost whitish; antennæ with ten branched segments, the branches being single, the longest (about flagellar segment four or five) a little longer than the segment; branch of the first segment appearing merely as a stout spur that is about as long as the glabrous apical pedicel of the segment. Head brownish gray, clearer gray on the posterior orbits.

Mesonotal praescutum brownish yellow laterally, the disk chiefly occupied by reddish brown, the median stripe passing into dark brown; scutum and scutellum pale yellow, each scutal lobe traversed by a dark brown line that passes into the scutellum, converging toward a central point; postnotum with the median area darkened, the lateral margins pale. Pleura yellow, the surface largely covered by two narrow longitudinal brownish black stripes. Halteres black, the base of the stem pale yellow, the apices of the knobs obscure yellow. Legs with the coxæ yellow, more or less darkened basally; trochanters yellow; femora yellowish brown to brown, the tibiæ and tarsi yellow, the terminal tarsal segments darkened. Wings with the ground-color creamy-yellow, the surface largely covered by extensive brown and gray clouds, including a costal series of about six of the former, these more extensive than the interspaces; broad brownish gray seams along the cord, outer end of cell *1st* M_2 and as marginal clouds at ends of some of the longitudinal veins; the paler gray areas occupy most of the remaining surface of the wings, including streaks near the outer ends of the marginal radial and medial cells; axillary region pale; veins yellow, darker in the infuscated areas. Venation: Sc_1 ending just beyond midlength of Rs, Sc_2 at its tip; Rs long, gently arcuated; free tip of Sc_2 a short distance beyond R_2; *m-cu* close to fork of M.

Abdominal tergites brownish yellow, the sternites brighter yellow, the basal segments narrowly margined laterally with black lines; hypopygium yellowish. Male hypopygium with the tergite transverse, the caudal margin gently emarginate, the broad lobes with conspicuous setæ. Ventral dististyle with the spines of the rostral prolongation placed beyond midlength, small, spike-like, close together. Dorsal dististyle gently curved, more expanded near outer end, terminating abruptly in an acute spine.

HABITAT: Ecuador. *Holotype*, ♂, Pallatanga, altitude 4400 feet, April 1, 1922 (G. H. H. Tate).

The only allied regional species is *L.* (*R*). *unipectinata* (Williston) which has all details of coloration of the wings and legs distinct.

Limonia (Rhipidia) paraguayana sp. n.

Belongs to the *domestica* group; general coloration brownish yellow, the thorax variegated with brown; postnotal mediotergite with a velvety-black triangular area; legs yellow, the outer tarsal segments darkened; wings pale yellow, dotted with brown and gray; male hypopygium with the spines of the rostral prolongation of the ventral dististyle long and slender.

Male. Length about 5.5 mm.; wing, 6.8 mm.

Rostrum and palpi black. Antennæ with the scapal segments brownish black, the flagellum extensively pale yellow, the central portion of each flagellar segment a trifle infuscated, the incisures thus

remaining broadly pale; flagellar segments (♂) almost simple, little if any produced. Head dark brownish gray; anterior vertex reduced to a linear strip.

Mesonotal praescutum chiefly pale brownish yellow, with a broad brown median stripe that becomes darker and better delimited on the posterior half of the sclerite; indications of narrow lateral brown stripes before the suture; scutal lobes extensively dark brown, ringed with brownish black; median area of scutum and the scutellum pale yellowish gray; postnotal mediotergite with a large black triangle on anterior half, the caudal and lateral portions of the sclerite pale. Pleura chiefly pale brownish yellow, narrowly lined ventrally with dark brown. Halteres pale yellow. Legs with the coxæ chiefly pale, the bases traversed by a narrow dark brown line; trochanters yellow; remainder of legs yellow, only the outer tarsal segments darkened. Wings pale yellow, with an abundant brown and gray dotting in all the cells; the more conspicuous brown areas are small and restricted, distributed as follows: Above the arculus; at supernumerary crossvein in cell *Sc*; origin of *Rs*; tip of *Sc*; stigma; along cord and outer end of cell *1st* M_2; the gray dots are scattered in all cells, variable in size, some very small, others larger and tending to become confluent; veins pale, darker in the infuscated areas. Venation: A supernumerary crossvein in cell *Sc*; Sc_1 ending about opposite midlength of *Rs*, Sc_2 at its tip; *m-cu* before the fork of *M*.

Abdominal tergites chiefly brownish, the sternites paler, more yellowish, narrowly lined laterally with black; hypopygium yellow. Male hypopygium with the tergite transverse but relatively wide, narrowed outwardly, the caudal margin very gently emarginate. Ventral dististyle of moderate size, fleshy, the rostral prolongation long and conspicuous, with two or three long, gently curved spines, in the type there being three such spines on one style and only two on the other; the spines are placed shortly before the outer end of the prolongation, the innermost a little the shorter, the longest spine approximately two-thirds the length of the prolongation alone.

HABITAT: Paraguay. *Holotype*, ♂, Villarica, July 15, 1928 (F. Schade).

L. (*R.*) *paraguayana* is most closely allied to *L.* (*R.*) *shannoni* (Alexander) of Eastern North America, which differs especially in the structure of the male hypopygium, the spines of the rostral prolongation of the ventral dististyle being short and stout.

Limonia (Rhipidia) schadei sp. n.

Belongs to the *domestica* group; general coloration of thorax dark brown, the praescutum obscure yellow with a brown median stripe; antennal segments (♂) a little produced; wings saturated brownish yellow, sparsely patterned with brown;

stigma pale, encircled by a dusky ring; abdominal tergites bicolorous.

Male. Length about 6–6.4 mm.; wing, 7.2–7.7 mm.

Rostrum and palpi black. Antennæ black, the apical pedicels of the flagellar segments white; flagellar segments strongly produced, so the base of each segment appears triangular. Head blackish gray; eyes above contiguous or virtually so.

Pronotum brownish black. Mesonotal praescutum obscure yellow with a median brown stripe; scutal lobes infuscated, the center of each lobe obscure yellow; median region of scutum whitish testaceous; scutellum dusky, pale posteriorly; postnotum dark brown. Pleura chiefly dark brown, sparsely pruinose, the ventral pleurites abruptly pale. Halteres obscure yellow, the knobs weakly infuscated. Legs with the coxæ yellow, the bases dark brown; trochanters yellow; femora yellow, with a scarcely indicated darker subterminal ring; tibiæ and tarsi obscure yellow, the latter passing into dark brown. Wings saturated brownish yellow, the outer radial cells a little more infuscated; stigma pale, encircled by a dusky ring; narrow or restricted brown seams at origin of *Rs*, fork of *Sc*, along cord and outer end of cell *1st* M_2; posterior prearcular cells and axillary region dusky; veins dark brown, *C*, *Sc*, most of *R*, *Cu* and the *Anal* veins except at tips yellow. Venation: Sc_1 ending just beyond midlength of *Rs*, Sc_2 at its tip; cell *1st* M_2 relatively small; *m-cu* just beyond the fork of *M*.

Abdominal tergites bicolorous, yellow, the caudal and lateral portions narrowly dark brown; subterminal segments more extensively darkened; hypopygium obscure yellow; sternites chiefly pale yellow. Male hypopygium with the tergite transverse, the caudal margin very gently emarginate. Ventral dististyle with the rostral prolongation conspicuous, the two spines unusually long and prominent, nearly as long as the prolongation itself, gently curved and directed slightly basad.

HABITAT: Paraguay. *Holotype*, ♂, Santa Barbara, September 4, 1925 (F. Schade). *Paratype*, ♂, Villarica, June 30, 1925 (F. Schade).

I take great pleasure in dedicating this crane-fly to the collector, Mr. F. Schade, to whose efforts we owe most of our knowledge of the Tipulidæ of Paraguay. *L.* (*R.*) *schadei* is allied to *domestica* (Osten Sacken) being separated especially on the uniformly darkened, more strongly pectinate antennal flagellum, the body-coloration, and the structure of the male hypopygium.

Limonia (**Geranomyia**) **austroandina** sp. n.

Belongs to the *canadensis* group; allied to *argentinensis* (Alexander); male hypopygium with the caudal margin of the tergite deeply notched; rostral spines of ventral dististyle

arising from very long, conspicuous swollen bases, especially the inner spine, the base of which is approximately twice as long as that of the outer spine.

Male. Length (excluding rostrum) about 6 mm.; wing, 7 mm.; rostrum about 4.3 mm.

Female. Length (excluding rostrum) about 7.5 mm.; wing, 6.8 mm.; rostrum about 4 mm.

Rostrum elongate, as shown by the measurements, dark brown, more yellowish at base. Antennæ with the scapal segments brownish yellow, the flagellum dark brown. Head gray, the posterior vertex and occiput broadly obscure yellow.

Mesonotal praescutum gray, largely covered by four darker plumbeous-gray stripes, the humeral region more yellowish; remainder of mesonotum dark gray, the scutellum obscure yellow, the median region of the scutal lobes obscure brownish yellow. Pleura reddish brown, pruinose. Halteres pale, the knobs infuscated. Legs with the coxæ and trochanters reddish yellow; femora obscure yellow, the tips narrowly dark brown; tibiæ obscure yellow, the tips even more narrowly darkened; tarsi passing into dark brown. Wings subhyaline, the oval stigma brown; veins brown. Venation: Sc_1 ending opposite midlength of *Rs*, Sc_2 at its tip; a weak supernumerary crossvein in cell *Sc*; *Rs* arcuated to weakly angulated at origin; *m-cu* at or before the fork of *M*, subequal to the distal section of Cu_1.

Abdominal tergites dark brown, the caudal margins of the segments narrowly and restrictedly pale; sternites more yellow, the outer segments darkened. Male hypopygium with the tergite transverse, the caudal margin with a deep V-shaped median notch, the lobes with numerous conspicuous setæ. Basistyle of moderate size, the ventro-mesal lobe large, with a smaller fleshy lobule near base. Dorsal dististyle a slender, very strongly curved hook, gradually narrowed into a long slender tip. Ventral dististyle very large and fleshy; rostral spines long and conspicuous, the outer arising from a long basal tubercle, the inner spine arising from a very long pale cylindrical tubercle that is about twice as long as the base of the outer spine; both spines slender, the outer a trifle the longer. Gonapophyses with the mesal apical lobe produced into a long narrow blade that is longer than the length of the base of the apophysis.

HABITAT: Argentina. *Holotype*, ♂, Cienega, near Agua Amarilla, Catamarca, altitude 3000 meters, February 12, 1923 (V. Weiser). *Allotopotype*, ♀, with the type.

L. (G.) austroandina is quite distinct from the allied and generally similar *L. (G.) argentinensis* (Alexander), in the peculiar modifications of the male hypopygium, as described.

Shannonomyia Alexander.

Shannonomyia argenticeps sp. n.

General coloration pale brownish yellow; antennæ with the basal three segments light yellow, the remainder dark brown; head silvery; legs yellow; wings fulvous-yellow, with a restricted brown pattern appearing as dark seams to the cross-veins and deflections; R_2 at fork of R_{3+4}.

Female. Length about 5.5 mm.; wing, 5.8 mm.

Rostrum and palpi dark brown. Antennæ (♀) short, the first three segments pale yellow, the succeeding segments abruptly dark brown; flagellar segments oval, gradually decreasing in size outwardly, the verticils a little longer than the segments. Head almost covered by a dense silvery pruinosity, the genæ more yellowish.

Mesonotum pale brownish yellow, without dark markings, the surface very vaguely pruinose. Pleura somewhat more testaceous yellow. Halteres obscure yellow. Legs with the coxæ and trochanters yellow; remainder of legs yellow, only the outer tarsal segments a little darker. Wings with a strong fulvous-yellow tinge, the prearcular and costal regions clearer yellow; very restricted brown seams at origin of *Rs*, on R_2, along cord and outer end of cell *1st* M_2; a whitish marginal spot at apex of cell R_4; veins yellow, darker in the infuscated areas. Venation: *Sc* pale, both Sc_1 and Sc_2 ending before the fork of *Rs*, the latter short, angulated at origin; R_2 at fork of R_{3+4}; veins R_3 and R_4 strongly diverging, cell R_3 at margin more than twice R_2; cell *1st* M_2 long, gently widened outwardly, longer than vein M_3 beyond it; *m-cu* close to midlength of cell *1st* M_2.

Abdomen yellowish brown. Tergal valves of ovipositor long and slender, acicular, gently upcurved.

HABITAT: Ecuador. *Holotype*, ♀, Ventura, altitude 1400 feet, April 11, 1922 (G. H. H. Tate).

Shannonomyia argenticeps is very distinct from the numerous regional species of the genus.

Shannonomyia paraguayensis sp. n.

General coloration buffy brown, sparsely pruinose; legs and halteres yellow; wings yellowish, the stigma very pale brown; veins yellow; Sc_2 at extreme tip of Sc_1; abdominal tergites dark brown, the ninth segment yellow; male hypopygium with the outer dististyle unusually short and stout.

Male. Length about 5.5 mm.; wing, 6 mm.

Rostrum and palpi black, the former pruinose. Antennæ with the scapal segments brownish yellow, the basal flagellar segments light

brown, the outer segments passing into black; flagellar segments oval, with elongate verticils. Head light gray.

Pronotum brownish gray. Mesonotum buffy brown, the praescutum with the median region somewhat darker, the surface sparsely pruinose; pseudosutural foveæ very small, comma-shaped. Pleura buffy, the anepisternum darker. Halteres pale. Legs with the coxæ and trochanters yellow; remainder of legs obscure yellow, only the outer tarsal segments restrictedly darkened. Wings with a strong yellow suffusion, the oval stigma very pale brown; veins yellow. Venation: Sc_1 ending about opposite two-thirds the length of *Rs*, Sc_2 at its extreme tip; *Rs* strongly arcuated at origin; cell *1st* M_2 widened outwardly; *m-cu* about one-half its length beyond the fork of *M*.

Abdominal tergites dark brown; basal sternites obscure yellow, narrowly infuscated laterally; outer sternites dark brown; ninth segment yellow; remainder of hypopygium dark brown. Male hypopygium with the outer dististyle unusually short and stout, widened beyond midlength, the apex with two blackened teeth, the outer shorter and more slender. Inner dististyle short, gently curved.

HABITAT: Paraguay. *Holotype*, ♂, Villarica, July 28, 1925 (F. Schade).

In its general appearance, *Shannonomyia paraguayensis* is most similar to *S. lentina* (Alexander) and *S. lentoides* (Alexander), of Middle America. It is very different in appearance from other regional species.

Atarba Osten Sacken.

Atarba (Atarba) brevicornis sp. n.

General coloration yellow; antennæ (♂) relatively short, bicolorous; legs yellow, the terminal tarsal segments darkened; wings light yellow; *Sc* short; *m-cu* before the fork of *M;* subterminal segments of abdomen (♂) extensively blackened; male hypopygium with the median region of the tergite produced into a conspicuous depressed rectangular lobe that divides into two divergent horns; aedeagus large.

Male. Length about 5 mm.; wing, 5.5 mm.

Rostrum obscure yellow, the palpi dark brown, the basal segment pale. Antennæ (♂) unusually short for this sex, if bent backward extending about to the base of the halteres; scapal segments yellow; basal flagellar segments bicolorous, the basal portion yellow, the remainder dark brown; on the first segment, the yellow equals the brown in amount; on succeeding segments the yellow decreases in area, on about the eighth flagellar segment becoming obsolete, the outer segments uniformly darkened; basal flagellar segment cylindrical, the outer segments long-oval. Head brownish yellow.

Mesonotum yellow, the postnotum slightly whitish pruinose. Pleura brownish yellow, the surface sparsely pruinose. Halteres pale. Legs yellow, the femoral tips not darkened, the tarsal segments beyond the first dark brown. Wings light yellow; stigma lacking; veins brighter yellow. Macrotrichia of veins shorter and less conspicuous than in *fiebrigi*. Venation: Sc_1 ending opposite the origin of *Rs*; *Rs* relatively short, angulated at origin; anterior branch of *Rs* relatively short, cell R_1 at margin being unusually wide, more than twice R_2; basal section of R_5 straight, about three-fourths the length of *Rs*; cell *1st* M_2 small; *m-cu* before the fork of *M*, the distance equal to one-third or one-fourth *m-cu*.

Abdomen obscure yellow, the tergites more or less darkened medially; a broad brownish black subterminal ring involving segments six to eight and the caudal portion of five; hypopygium yellow. Male hypopygium with the median region of the sternite produced into a conspicuous depressed long-rectangular lobe, the apex of which is further split into two divergent horns. Outer dististyle moderately slender, the teeth relatively small and scattered. Gonapophyses large and not especially spinous. Aedeagus large, constricted before mid-length, with a ridge-like collar immediately basad of this.

HABITAT: Paraguay. *Holotype*, ♂, Villarica, February 12, 1926 (F. Schade).

Atarba brevicornis is distinct from all of the numerous species of the genus in Tropical America. It agrees with *megaphallus* Alexander (Brazil) in the large size of the aedeagus but in the coloration of the antennæ agrees better with *fiebrigi* Alexander (Paraguay) and similar species, from all of which it differs most evidently in the unusually short antennæ of the male sex.

Atarba (Atarba) tatei sp. n.

General coloration brownish yellow; antennal flagellum uniformly brownish black; legs yellow, the tips of the femora narrowly and conspicuously blackened; wings grayish yellow, the stigma small and only slightly darker than the ground-color; *Rs* very short, about two-thirds the basal section of R_5; cell *1st* M_2 short and nearly square; abdominal tergites dark brown, the basal segments weakly bicolorous; hypopygium yellow, the outer dististyle with only a few coarse spines on outer margin.

Male. Length about 5 mm.; wing, 6 mm.

Female. Length about 5.5 mm.; wing, 6.8 mm.

Rostrum light brownish yellow, the palpi darker brown. Antennæ with the basal segments of the scape dark brown, the second segment

paler; flagellum brownish black, the segments gradually decreasing in length and diameter outwardly, the terminal segment shorter and paler than the others; verticils of all except the outer segments shorter than the segments. Head chiefly infuscated.

Mesonotum brownish yellow, unmarked, the pleura more testaceous yellow. Halteres pale, the knobs slightly infuscated. Legs with the coxæ and trochanters yellow; femora yellow, the tips narrowly but conspicuously blackened; tibiæ and tarsi yellow, the outer segments of the latter darkened. Wings grayish yellow, the costal region clearer yellow; stigma, small oval, only a little darker than the ground-color; veins brownish yellow. Venation: Sc_1 ending shortly before Rs, the latter very short, about two-thirds the length of the basal section of R_5 and in alignment with it; cell *1st* M_2 unusually short and nearly square; *m-cu* shortly beyond the fork of *M*

Abdomen with the basal tergites weakly bicolorous, the remainder dark brown, especially the subterminal segments; hypopygium yellow; basal sternites clear pale yellow. Male hypopygium with the outer dististyle unusually slender and attenuated, the spines along the outer margin large and coarse, especially the three intermediate ones; beyond this point, the apex is slender, blackened, bearing a lateral spine close to tip. The sternal plate is broader than long.

HABITAT: Ecuador. *Holotype*, ♂, Pallatanga, altitude 4400 feet, April 1, 1922 (G. H. H. Tate). *Allotopotype*, ♀, March 26, 1922. *Paratopotype*, ♂, with the allotype.

The species is named in honor of the collector. By my key to the American species of *Atarba* (Ann. Ent. Soc. America, 19:171; 1926), this species runs to *brunneicornis* Alexander (Colombia), a very different species that has the femora uniformly yellow and the details of venation distinct.

Gnophomyia Osten Sacken.

Gnophomyia pallidapex sp. n.

General coloration black, the lateral angles of the pronotal scutellum yellow; wings blackish, the outer cells extensively paler; R_{2+3+4} and R_{2+3} subequal; *m-cu* beyond midlength of the long cell *1st* M_2; abdomen, including the hypopygium, black.

Male. Length about 6 mm.; wing, 6 mm.

Female. Length about 7 mm.; wing, 6.2 mm.

Rostrum and palpi black. Antennæ black throughout, relatively elongate (♂), if bent backward extending to beyond the base of the abdomen; flagellar segments elongate-oval. Head black, the anterior vertex a little dusted with gray.

Thorax entirely black with the exception of the lateral angles of the pronotal scutellum which are yellow. Halteres and legs entirely black.

Wings with a strong blackish tinge, the cells beyond the level of the outer end of cell *1st* M_2, as well as the outer ends of the cubital and anal cells conspicuously paler; veins black. Venation: *Rs* short, very gently arcuated, in alignment with R_5; R_{2+3} subequal to R_{2+3+4} and equal to or only a little shorter than R_{1+2}; veins R_3 and R_4 nearly parallel, diverging very gradually; cell *1st* M_2 elongate, with *m-cu* beyond midlength; veins issuing from the cell rather elongate.

Abdomen, including hypopygium, black. Male hypopygium with the tergite large, its caudal margin nearly transverse, fringed with setæ. Outer dististyle long and slender, glabrous, gently curved to the obtuse apex. Inner dististyle very short, the tip enlarged and obtuse, the stem with long conspicuous setæ, some of which virtually equal the style in length.

HABITAT: Paraguay. *Holotype*, ♂, Santa Barbara, October 17, 1925 (F. Schade). *Allotopotype*, ♀. *Paratype*, ♂, Molinasque, Department of Caragua, November 9, 1925 (F. Schade).

Gnophomyia pallidapex is very distinct from the known Neotropical species of the genus in the peculiar coloration of the wings.

Gonomyia Meigen.

Gonomyia (Progonomyia) pleurolineata sp. n.

General coloration yellowish, the dorsal pleura striped longitudinally with dark brown; wings grayish yellow, the stigma barely evident; R_2 very faint to subobsolete, placed just before the fork of R_{3+4}; *m-cu* shortly before the fork of *M;* male hypopygium with the outer dististyle having the dilated blackened head trilobed.

Male. Length about 5.3 mm.; wing, 6.3 mm.

Rostrum pale, more brownish pruinose above; palpi black. Antennæ with the basal segment obscure yellow; second segment black, the base paler; flagellum black, the segments long-oval with verticils that do not exceed the segments. Head gray, the center of the vertex a little infuscated.

Anterior lateral pretergites light sulphur-yellow. Mesonotal praescutum dark, pruinose, more intense in front, the humeral region light sulphur-yellow; posterior sclerites of mesonotum more yellowish, especially the scutellum. Pleura yellow, striped longitudinally with darker, including a broad dorsal darker brown stripe; sternopleurite weakly darkened ventrally. Halteres pale, the knobs slightly darkened. Legs with the coxæ brownish yellow, the fore coxæ more darkened; trochanters yellow; femora obscure yellow, the tips somewhat darker; tibiæ yellowish brown; tarsi passing into dark brown. Wings grayish yellow, the stigma barely evident; veins brown. Venation: *Sc* long, Sc_1 ending beyond midlength of the long gently arcuated *Rs*, Sc_2 some

distance from its tip, Sc_1 alone about one-half longer than *m-cu;* R_2 very faint to subobsolete, placed just before the fork of R_{2+4}; cell *2nd* M_2 deep; *m-cu* shortly before the fork of *M*.

Abdomen yellowish brown, the hypopygium somewhat brighter. Male hypopygium with the outer dististyle distinctly trifid, the enlarged blackened head being divided into two pincer-like major arms, one flattened and obtuse, the other more curved and terminating in a blackened subacute point; besides these, at their bases, a shorter more triangular branch or lobe. Inner dististyle arcuated beyond base, the distal portion smooth, the apex obtusely rounded, the surface without punctures. Apex of aedeagus weakly trifid.

HABITAT: Argentina. *Holotype*, ♂, Quebrada "Volcan," at Agua Amarilla, Catamarca, January 29, 1922 (V. Weiser).

Gonomyia pleurolineata is readily told from all allied species by the coloration of the body and wings and the structure of the male hypopygium. The only other regional species so far described with a tripartite outer dististyle is *G. weiseri* Alexander, an otherwise very different fly.

Gonomyia (Gonomyia) catamarcæ sp. n.

Allied to *G. andicola* Alexander; general coloration of mesonotum yellowish brown; rostrum yellow; antennæ entirely blackened; halteres elongate, dusky; wings grayish, the stigma poorly defined; petiole of cell R_3 elongate; *m-cu* before the fork of *M;* male hypopygium with the outer dististyle a simple rod, the apex truncated; phallosome with the apophyses symmetrical, slender, each bifid at apex.

Male. Length about 5 mm.; wing, 6.4 mm.

Rostrum yellow; palpi dark brown. Antennæ black, the first segment a trifle brightened at base; antennæ relatively long for a member of this genus, if bent backward extending nearly to the wing-root. Head pale, shrunken in the type, the vertex apparently infuscated.

Anterior lateral pretergites whitish yellow. Mesonotum light yellowish brown, without distinct markings, the scutellum a trifle more yellow. Pleura chiefly pale yellow, with a vague dusky area extending from the propleura onto the anepisternum; sternopleurite more reddish yellow. Halteres elongate, dusky. Legs with the coxæ and trochanters pale yellow; femora pale brown, brighter basally, the tips darker brown; tarsi dark brown. Wings rather strongly narrowed at base, grayish, the stigma very pale; veins brown, *Sc* more yellowish. Venation: Sc_1 ending just beyond the origin of *Rs*, Sc_2 an equal distance before this origin; *Rs* almost in alignment with R_2, the basal section of the latter obliterated or nearly so; petiole of cell R_3 elongate, gently arcuated, nearly twice vein R_3; cell *1st* M_2 long-rectangular, subequal to vein M_4 beyond it; *m-cu* about one-half its length before the fork of *M*.

Abdominal tergites brownish yellow, indistinctly lined longitudinally with brown, most evident medially; sternites pale yellow; hypopygium yellow. Male hypopygium with the tergite produced medially into a lobe that divides into divergent arms. Basistyle with a relatively small, elongate-oval dusky lobe. Outer dististyle a long, pale, fleshy structure, the outer surface and apex with setæ. Inner dististyle a simple, nearly straight rod, the basal half more dilated, the outer margin with numerous setæ, including two powerful flattened ones; distal portion of style narrow, straight, the apex truncated, before the tip with a single powerful seta. Phallosome long and slender, the aedeagus extending slightly beyond the subtending apophyses, the latter symmetrical, elongate, each split into two acute spines at tip.

HABITAT: Argentina. *Holotype*, ♂, Bolson, Catamarca, altitude 2700 meters, March 7, 1924 (V. Weiser).

The only allied species so far made known is *G.* (*G.*) *andicola* Alexander (Colombia), which differs in the dark coloration, the venation, and structure of the male hypopygium.

Molophilus Curtis.

Molophilus substylifer sp. n.

Belongs to the *plagiatus* group; closely allied to *M. stylifer* Alexander, differing especially in the wing-shape, venation, and details of structure of the male hypopygium.

Male. Length, excluding head, about 3 mm.; wing, 3.5 mm.

Head broken. General coloration of mesonotum light brown, variegated with darker brown, the postnotum dark brown. Pleura chiefly dark. Halteres obscure yellow, the knobs weakly darkened. Legs with the coxæ brownish yellow; trochanters yellow; femora yellow basally, more infuscated outwardly; tibiæ and tarsi passing into brown. Wings whitish subhyaline, the veins conspicuous, brown; prearcular and costal regions more yellowish. Wings broader than in *stylifer*, the caudal margin opposite the anal veins not concave, as in the latter species. Venation: R_{2+3} more oblique in position; vein *2nd A* longer, ending about opposite the caudal end of vein *m-cu*.

Abdomen brown, the hypopygium somewhat brighter. Male hypopygium with the basistyle having the terminal beak relatively slender, without a basal shoulder, as in *stylifer*. Outer dististyle with both arms subequal in length and subacute at tips; in *stylifer*, the lateral arm is much shorter and truncated. Basal dististyle a long straight rod that narrows to an acute point, the short lateral spine placed at or slightly beyond one-third the length.

HABITAT: Argentina. *Holotype*, ♂, Bolson, Catamarca, altitude 2750 meters, March 9, 1924 (V. Weiser).

The antennæ of the male of *Molophilus stylifer* are unusually elongate; the condition in the present species is unknown.

Molophilus pallatangensis sp. n.

Belongs to the *plagiatus* group; allied and generally similar to *M. perseus* Alexander, differing especially in the coloration and wing-pattern.

Male. Length about 3.5–3.7 mm.; wing, 4.5–4.7 mm.

Rostrum and palpi dark brown. Antennæ (♂) of moderate length, if bent backward extending nearly to the root of the halteres; scapal segments dark, the flagellum brownish yellow; flagellar segments subcylindrical, with a short dense white pubescence. Head dark gray.

Posterior pronotum pale yellow. Mesonotum dark brownish gray, the humeral region of the praescutum brighter yellow. Pleura dark gray. Halteres pale yellow, the base of the stem and the knobs lighter yellow. Legs with the coxæ and trochanters testaceous yellow; femora obscure yellow, darker outwardly; tibiæ and tarsi darker brown. Wings whitish subhyaline, the veins darker, conspicuously seamed with brown clouds to produce a more or less streaked appearance, the more evident seams being along the cord and along the main veins basad of the cord; veins pale yellow, somewhat darker in the clouded areas. Macrotrichia pale brown, the long costal fringe and conspicuous patches along the cord and on veins *Cu* and *2nd A* darker brown and more conspicuous. Venation: Almost as in *perseus;* vein *2nd A* extending to slightly beyond *m-cu*.

Abdominal tergites brownish black, the sternites more obscure yellow; hypopygium dark brown. Male hypopygium with the beak of the basistyle simple, the base relatively stout. Basal dististyle generally similar to that of *perseus*, appearing as a strong rod that is extended into a powerful apical spine, the outer margin provided with a series of ten or more spines, the basal ones shorter and appressed, the outer ones longer and more erect.

HABITAT: Ecuador. *Holotype*, ♂, Pallatanga, altitude 4400 feet, March 28, 1922 (G. H. H. Tate). *Paratopotypes*, 2 ♂♂, March 26–28, 1922 (G. H. H. Tate).

The thorax of the type of *M. perseus* was described as being light yellowish brown but a paratype female in my collection is much darker, more grayish brown. It seems possible that more than a single species is confused in the series. *M. pallatangensis* differs most evidently in the conspicuously patterned wings, with dark veins and patches of dark macrotrichia.

Molophilus paraguayanus sp. n.

Belongs to the *plagiatus* group; general coloration brownish gray; antennæ brownish black; male hypopygium with the basal dististyle broadly expanded on basal two-fifths, the

mesal edge with abundant appressed spinous setæ, the apical portion abruptly narrowed into a slender spine.

Male. Length about 3.5–3.6 mm.; wing, 4.3–4.4 mm.

Female. Length about 4.2 mm.; wing, 4.5 mm.

Rostrum and palpi black. Antennæ (♂) brownish black, of moderate length, if bent backward extending about to the wing-root. Head brownish gray.

Mesonotum brownish gray, the anterior lateral pretergites and restricted humeral region light sulphur-yellow; pseudosutural foveæ elongate, dark-colored. Pleura darker brown, the dorso-pleural region pale. Halteres yellow, the knobs weakly infumed. Legs with the coxæ testaceous yellow, the fore coxæ somewhat darker; trochanters yellow; femora obscure yellow, the outer ends darkened; tibiæ and tarsi dark brown. Wings tinged with brown, the costal region brighter, more yellowish; veins brown, the macrotrichia still darker brown. Venation: R_2 lying shortly beyond the level of *r-m;* vein *2nd A* ending just before the outer end of *m-cu*.

Abdomen dark brown, the sternites in male weakly bicolorous, obscure yellow with the caudal margins narrowly dark brown, in the female more uniformly darkened; hypopygium dark. Male hypopygium with the apical beak of the basistyle slender, blackened. Basal dististyle with about the basal two-fifths greatly expanded, the mesal edge with abundant appressed spinous setæ, the apical portion abruptly narrowed into a slender spine. Aedeagus sinuous.

HABITAT: Paraguay. *Holotype*, ♂, Villarica, February 1, 1925 (F. Schade). *Allotopotype*, ♀, June 10, 1925. *Paratopotypes*, 1 ♂, with the allotype; 1 ♀, with the type.

Molophilus paraguayanus is very distinct from all species in the structure of the male hypopygium.

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DATES OF ISSUE FOR VOLUME XXII.

March Number—March 15, 1929.
June Number—June 22, 1929.
September Number—October 12, 1929.
December Number—December 10, 1929.